ECOLOGICAL ASPECTS OF THE BIRD HAZARD PROBLEM

AT CHRISTCHURCH INTERNATIONAL AIRPORT

A thesis presented for the degree of

Doctor of Philosophy in Zoology

in the

University of Canterbury

Christchurch, New Zealand

by

Abdul Moeed

1970

CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

1. GENERAL INTRODUCTION

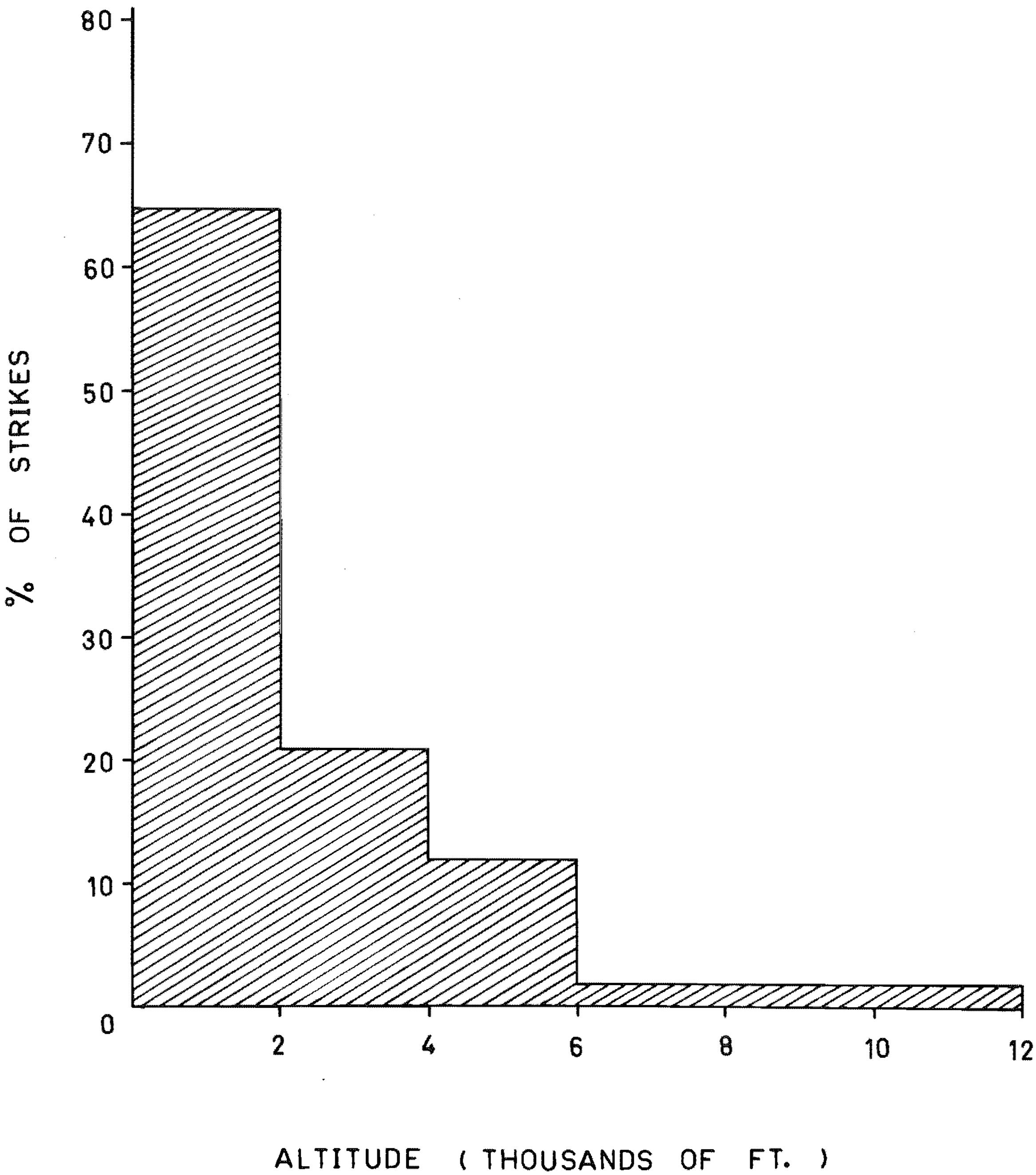
1.1 Introduction

Birds as a group have long been of interest for either economic, scientific, aesthetic or emotional reasons, but during the last few decades, with the diversification in human interests, some species have come to be regarded as undesirable at certain places, especially when they occur in abundance. Airfields provide a classic example of places where birds actually endanger human life. Much work has been done on this problem around the world, but no one method of approach has so far been totally effective.

1.2 History and origin

It is more than two decades since the aviation industry began experiencing bird strikes on aircraft. The record of these strikes in the early stages of aviation is inadequate. It was only during the Second World War that the problem was considered by military agencies at bases on oceanic islands, notably at Midway in the North Pacific and Ascension in the South Atlantic (Aldrich, Robbins and Dykstra, 1961).

Bird strikes on aircraft are always possible as both occasionally fly in the same airspace. The degree of danger is proportional to the flight frequency of aircraft and bird density at altitudes used by both. Apart from migratory flocks, greater bird concentrations occur at lower altitudes, and therefore commercial aircraft mostly encounter birds near airfields while landing or taking off, and rarely when cruising. Military aircraft on the other hand, often fly at low altitude throughout their flight regime and may strike birds on or away from airfields. The bird strikes to commercial aircraft have been shown (Fowler, 1967) to decrease with increasing altitude (Fig. 1).



80
70
60
50
40
30
20
10
0
% OF STRIKES
2
4
6
8
10
12
ALTITUDE (THOUSANDS OF FT.)

Figure 1

Percentage occurrence of bird strikes with altitude (adapted from Associate Committee on Bird Hazards to Aircraft, National Research Council, Canada, Field Note 42).

With the progressive increase in aircraft speed, the danger of hitting birds has increased enormously. Although birds avoid objects which may prove dangerous to them, they have not yet developed a fear of aircraft as they have for natural predators. Only when they appear to be in danger from approaching aircraft do they attempt evasive action, and then it is frequently too late (Bird, 1965).

1.3 Extent of damage

While it is difficult to assess the agricultural damage caused by birds, their impact on aviation is enormous, both in terms of monetary loss and risk to human life. Kuhring (1963a) noted that minor damage to piston engines from bird strikes could easily cost $10,000 to $20,000 and a completely destroyed jet engine might cost $100,000 to $150,000 to replace. Two fatal air crashes involving commercial airlines have been the direct result of bird strikes. In the first (in 1960) an Electra crashed at Logan International Airport, Boston, Massachusetts, after running into a flock of Starlings just after take off; 62 of the 72 people on board died in the crash. Two years later in Maryland State a Viscount collided with a flock of Whistling Swans. Damage to the stabilizers caused the plane to crash, killing all seventeen persons on board. Despite the disastrous consequences, these crashes were of value in that they caused the initiation of co-ordinated research in many countries on the problem of bird presence on and around airfields.

1.4 Factors attracting birds to airfields

1.4B Location

There are few habitats without an avifauna, but frequently airfields attract more birds than adjoining areas. When most modern airfields were built, there was hardly any consideration of bird hazards. Consequently many were located on reclaimed land, near tidal zones and/or near swamps. In other cases areas fit for no other use were selected. These included localities close to rubbish dumps, abattoirs, sewage outlets, tanneries and fish processing areas. Such places have always been attractive sites to birds. Waders and waterfowl are attracted to the first set of habitats, while scavenging birds, especially gulls, are the dominant species in the second. The Black Kite (Milvus migrans) has also been reported to scavenge on such places (van Tets, 1966).

1.4B Availability of food and water

Apart from the main runways and taxiways, airfields are generally well grassed to hold the soil and prevent erosion. Dust and debris that would otherwise blow with plane movement is therefore contained.

In establishing a healthy pasture, fertile soil is applied which in turn attracts a diverse and abundant infauna. Thus carnivorous birds which normally feed in adjacent fields are attracted to the airfield to exploit this food source. Maturing grasses, weeds and berry-producing plants on the other hand provide an abundance of seeds to which seed-eating birds are attracted.

Birds of prey are sometimes attracted to airfields in search of small rodents or lizards that live among neglected vegetation. These birds, although not plentiful, constitute a hazard as they wheel and hover in search of prey.

Water collectors such as open drains, seasonal and permanent ponds on and off the airfields attract waterfowl either for feeding or roosting.

1.4C Availability of nest and roosting sites

The number of birds nesting on airfields depends upon the availability of suitable sites and the extent of disturbance by human agencies. On some airfields, administrative buildings, hangars and sheds are constructed so as to leave potential nesting sites for some species. Birds that have nested at one site usually return there to nest in subsequent seasons; young birds usually occupy the same habitat for this purpose. This leads to a gradual build up in the nesting population. At Midway Island thousands of Laysan Albatross (Diomedia immutabilis) used to nest close to the runways and despite various control measures including the killing of 29,764 birds in 1958 (Rice, 1959) some still nest on nearby areas. Cliff Swallows (Petrochalidon pyrrhonota) have been reported (Lewis, 1964) nesting in a hangar at Halifax International Airport, Nova Scotia. Constructions in close proximity to airfields also serve the same purpose.

Roosting sites on airfields are provided mainly by trees, shrubs and hedges, though administrative buildings, hangars and sheds sometimes serve in this capacity too. It has been suggested (Aldrich et al., 1961) that infrequently used runways and other undisturbed areas may be used as bird roosts. There will, however, be several factors influencing the selection of a roost, of which the extent of disturbance is only one.

In addition to the above factors, some airfields are subjected to seasonal influx of migratory birds while many others are affected by diurnal bird movements to and from roosts and feeding areas.

1.5 Review of possible control measures

Considerable work has been done throughout the world to combat the problem of birds striking aircraft. In the initial stages emphasis was laid on the mechanical factors such as protection of aircraft from bird strikes. Although this has obvious advantages, no method has yet been developed to make a "bird proof aircraft". Research towards this aim has revealed that it is a difficult if not impossible task. Consequently the role of biological factors has received new emphasis, and present research is directed towards finding a possible solution through a combination of mechanical and biological aspects of this problem.

1.5A Mechanical research

I. Windshields

Windshields of aircraft are very vulnerable to damage from bird strikes. With the result of experiments using a four pound "experimental bird" (Fowler and Levy, 1965a, 1965b) aircraft manufacturers have reached the stage of being able to make windshields that can resist impact from most birds (up to four pounds). One method (Hillaby, 1967; Stable and New, 1968) uses a thick layer of polyvinyl butryal between the glass layers. Being elastic the polyvinyl butryal prevents bird penetration. Although after impact his view is obstructed, the pilot can see through the undamaged portion of the windshield and the internal pressure of the flight deck is also maintained. To overcome the cooling effect on polyvinyl butryal at high altitude, a thin metallic layer has been introduced in between the glass layers and a temperature of 104°F is maintained by passing an electric current through the metal layer. This prevents the polyvinyl butryal layer from becoming brittle. However, factors like the rise in temperature due to kinetic heating, the differential expansion and contraction due to change in altitude and above all, the unknown weight of the colliding bird, necessitate a windshield of even greater strength.

II. Engines

Due to operational intricacies little has been done to protect engines. Jet engines are more vulnerable to bird damage than propeller driven ones. Besides the initial strike damage, the former are susceptible to further damage from material ingested in the air intake. Guards in front of jet engines are impractical because they increase air resistance drastically and decrease normal operating efficiency.

The possibility of a safe positioning of jet engines on the aircraft has been discussed (Ballantyne, 1963; Brown, 1963). It is doubtful whether any one position has advantages over another as bird strikes have been reported on planes with differently located engines.

III. Airframe protection

Enormous forces develop during bird strikes on airframes; these forces are correlated with the speed of the aircraft and the size, speed and the direction of the bird. Structural changes such as streamlining of the body, thinning of wings and reduction of surface friction have been made to serve the dual purpose of increasing efficiency and reducing bird strike damage.

1.5B Biological research

Another possibility of reducing bird strikes on aircraft seems to lie in the study of the biological aspects of the problem. By determining the causes of bird presence on airfields, it may be possible to implement an ecological programme to discourage birds from using the airfields and their surroundings.

Once a bird problem at an airfield is established, it becomes necessary to note the kinds of bird involved and the reasons for their presence. The importance of food sources, availability of water, nesting and roosting sites on and about the airfield, as a deciding factor for bird presence, cannot be over emphasized.

Possible measures that have been used to combat the presence of birds on and about airfields include the following:

a) removal of attractive habitat features;
b) retention of a deep sward of grass;
c) use of bird carcasses, falcons and dogs;
d) use of chemicals;
e) restriction of agricultural activities on the airfield and adjacent areas; and,
f) the use of bird detection and scaring devices.

I. Attractive habitat features

Removal of habitat features, such as the availability of food, water, roosting and nesting sites helps in reducing bird numbers in the area. Clearing of such topographic features as sand dunes has been suggested (Rice, 1959) for Sand Island's airfield in the North Pacific. The object here was to reduce the updraught on which some birds soared.

II. Retention of deep sward

Retention of a deep and thick sward of grass on an airfield pasture prevents many birds from settling; mostly because of the non-availability of subterranean and surface dwelling food items and partly because of the restricted all-round view. This measure, although effective in most cases, may result in a build up of rodent populations, which in turn attract birds of prey. An intermediate height of grass cover may help to reduce this problem and would be an effective measure at places with low rodent populations.

III. Use of bird carcasses, falcons and dogs

Stuffed bird carcasses have been used in an attempt to scare birds from airfields in Canada and the Netherlands. Carcasses were displayed as if attacked by birds of prey, but were found to be only temporarily successful (Hardenberg, 1963). Their effectiveness is limited to daylight only and all birds do not respond in the same way to corpses of their own species. Weathering and long usage of these carcasses reduces their effectiveness.

Trained falcons were used on Victoria International Airport, British Columbia (Solman, 1965) and at Leeuwarden air base, in the Netherlands (Flight and Ground Safety Section, R.Neth.A.F., May, 1969) to disperse birds. The universal use of falconry for such a purpose is of questionable value because of its operational limitations to daylight hours, the need of trained and dedicated operators and a dependable supply of trained falcons.

The use of dogs as a bird deterrent has been considered (Kuhring, 1963b; Munro and Harris, 1963) after it had been observed in the United States that gulls rarely frequent those dumps that are also used by dogs. However, results from any such experiments are not available.

IV. Use of chemicals

Chemicals emitting unpleasant odours have been considered as bird deterrents (ICAO, Working Paper AN-WP/2841, 1964) and naphthalene balls were used on an airfield in Great Britain, but the effect on birds was negligible; probably due to the rapid dispersal of vapours. The effectiveness of this method is dubious considering the poorly developed sense of smell in most birds (see Hess, 1951; Wallace, 1955; Welty, 1962) and its applicability on a public place such as an airport.

The possibility of reducing bird numbers by changing ground and grass colour with chemical use was attempted but without encouraging results (Board of Trade, Aerodromes (Technical) Directorate, DAT Paper No.14, 1969).

V. Restricted agricultural activity

There is a general agreement among authorities (Harris and Hatch, 1964; Harris and Gunn, 1964) that grain cropping in areas adjacent to airfields be discouraged in favour of hay crops. The advantage would be to remove the source of attraction for grain-eating birds.

VI. Bird detection and scaring devices

VI.a. Bird detection

The knowledge of bird presence on airfields and in the aircraft flight path is an important factor while planning safety measures. In this field two possibilities have been considered. Firstly, infrared equipment (Kuhring, 1963d) has been used for bird detection during the hours of darkness; it has, however, been reported that smaller birds are difficult to detect from a reasonable distance. Secondly, radar has been used successfully to detect and then plot movements of bird flocks during diurnal or migratory flights. Gunn and Solman (1968) have considered the possibility of detecting bird flights by radar and making this information available to the flight planning personnel at airfields. In this way bird movements in the area can be co-ordinated with the flight schedules to avoid the possibility of bird strikes.

VI.b. Scaring devices

VI.b.i. Distress calls

A useful method of dispersing birds from airfields involves broadcasting of pre-recorded distress calls. These calls are in use in many countries and results of this work are well documented (see Kuhring, 1963c; Cook-Smith, 1963; Hardenberg, 1963; Brown, 1962; Busnel and Giban, 1968; Brough, 1968). Cook-Smith expressed doubt about the permanent effectiveness of distress calls and reported that in one instance when these calls were in use for a year, birds were not responding as much as they did in the initial stages of its use. The actual causes of this reaction were not known, but they may have resulted either from deteriorated sound tracks due to long use of a tape, or the birds may have become accustomed to these calls. Kuhring reported that distress calls may become ineffective when used singly for a long time but the effectiveness can be re-established by combining them with mechanical scaring devices. Hardenberg pointed out the specific nature of these calls by citing an example where distress calls obtained from the Herring Gull (Larus argentatus) in the United States were found to be ineffective against the same species in the Netherlands. These calls do not always disperse every bird species, the Oystercatcher (Haematopus ostralegus) and the Jay (Garrulus sp.) have been reported by Hardenberg, to be attracted by their respective distress calls. It seems probable that limitations will always exist in using this method of scaring birds from airfields.

VI.b.ii. Mechanical devices

Various mechanical bird scaring devices have been developed. These are usually referred to as pyrotechnics and include the use of acetylene cannons or carbide exploders, shell crackers, Very flares, marine signal rockets, thunderflashes and live ammunition.

Carbide exploders are detonating devices that can be set to explode at regular intervals. They have been used with limited success, being ineffective in extreme cold weather and suffering from the disadvantage that birds become used to the explosion intervals. On an airfield in the United States birds were reported to be perching on the carbide gun between explosions (ICAO, Attachment to State Letter AN 4/8.1-64/92, 1964). It was thought that they did so to warm their feet. These exploders have advantages in that they do not require constant vigilance, and the operator is saved from the discomfort of high pitched explosions.

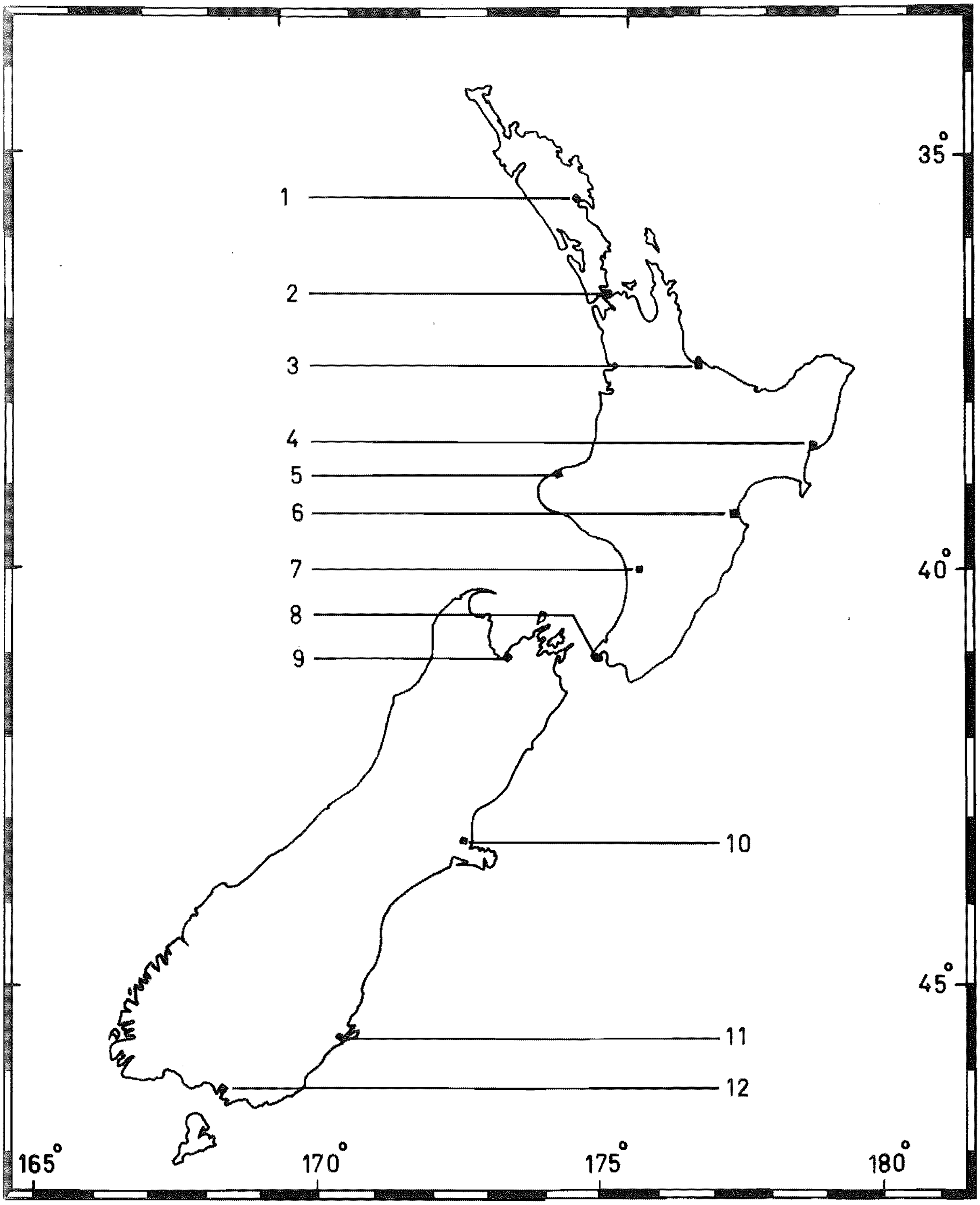
Shell crackers in the form of shot gun cartridges are now in use for dispersing birds. With these devices, the first explosion takes place at the site of firing while the second occurs when the projectile reaches the target (a flock of birds). Initially accidents occurred because of both explosions taking place within the barrel of the gun, but a reasonable standard of safety has now been attained.

Very flares and marine signal rockets are used to disperse birds put to flight by pre-recorded distress calls. The marine signal rocket climbs vertically to 300 feet while producing a trail of sparks on its way, and eventually dispersing more sparks when reaching maximum height. This helps in dispersing those birds that fly on top of the broadcasting equipment after being dislodged from the ground.

In addition to above-mentioned devices, the use of ultrasonic and supersonic sirens, microwaves and infrared beacons as bird deterrents have been considered. Ultrasonic and supersonic sirens will perhaps be more annoying to the public than to birds as there is a strong possibility of birds becoming used to the noise.

Use of microwave transmitters to remove birds from airfields and aircraft flight paths is at present in the developmental stages (Tanner, 1966; Tanner, Romero-Sierra and Davie, 1967, 1969; Tanner and Romero-Sierra, 1968a, 1968b). Microwaves have been reported to be dangerous to other vertebrates (Clark, 1950; Deichmann, Stephens, Keplinger and Lampe, 1959; Deichmann, Miale and Landeen, 1964), therefore its use as a bird deterrent on airfields is of doubtful value. The use of infrared beacons for the same purpose is in the experimental stages (T.A. Caithness, pers. comm.).

Up to this point the problem of bird hazard to aircraft has been reviewed mostly in the light of world wide research. Most of these methods of reducing bird numbers have universal application, but modifications will always be necessary to suit local conditions, because no two airfields will have the same type of problem. There may be similarities, but vital details



35°
40°
45°
165°
170°
175°
180°
1
2
3
4
5
6
7
8
9
10
11
12

Figure 2

Location of major New Zealand airfields.

Key to numbers:

1. Whangarei Airport
2. Auckland International Airport
3. Tauranga Airport
4. Gisborne Airport
5. New Plymouth Airport
6. Hawke's Bay Airport, Napier
7. Ohakea Airport
8. Wellington Airport
9. Nelson Airport
10. Christchurch International Airport
11. Momona Airport, Dunedin
12. Invercargill Airport

will vary radically due mainly to geographical distribution, topographic dissimilarities, environmental differences, inconsistent siting of airfields and differing avifaunas.

1.6 Bird hazard in New Zealand

The history of New Zealand aviation is so far free from any fatal accident involving bird strikes, but future strikes could have fatal results. Continued research and constant vigilance is necessary to maintain this enviable record. The inconvenience resulting from a minor bird strike is worth noting as they often cause unscheduled and expensive overhauls of airframes, engines or both (Caithness, 1968a).

The location of major New Zealand airfields is shown in Figure 2. Most lie within ten miles of the coast; some are on reclaimed land and still others are sited near rivers and lakes. The common factor is that all of them are located near aquatic habitats; these places are traditionally occupied by large numbers of birds which endanger the safety of aircraft operating from nearby airfields.

As a result of the 1963 Nice Symposium on bird hazards to aircraft, a National Committee was founded in New Zealand in 1964 to co-ordinate research on various airfields. The New Zealand Wildlife Service, of the Department of Internal Affairs, began preliminary studies on this problem at Whangarei Airport (Caithness, 1965; Saul, 1968); Auckland International Airport (Saul, 1967; Caithness, Williams and Bull, 1967); Tauranga Airport (Bull, 1965); Gisborne Airport (Caithness, 1966); Hawke's Bay Airport, Napier (Caithness and Williams, 1965; Caithness et al., 1967); Ohakea Airport (Bull, 1966a); Momona Airport, Dunedin (Williams, 1966a); Invercargill Airport (Williams, 1966b; Caithness et al., 1967); Wellington Airport (Bull, 1964; Williams and Caithness, 1965; Bull, 1966b) and Nelson Airport (survey conducted in 1964-65, formal report not available) while a research unit of the Department of Zoology, University of Canterbury, undertook investigations at Christchurch International Airport (Stonehouse, 1964, 1966). The main objective of these surveys was to evaluate the nature of bird hazards in relation to factors that influence bird presence, and if possible to recommend appropriate measures to reduce bird numbers on various airfields.

In general, the New Zealand approach to these problems is ecologically oriented. This seems appropriate, and likely to reach the root cause of the bird problem on and around airfields. The importance of bird scaring methods have not been totally neglected. Besides the use of some conventional methods, crucified polystyrene models of gulls (Caithness, 1969) and a mechanical hawk (Saul, 1967) have been used with limited success.

The record of bird strikes in New Zealand prior to June, 1965, is incomplete. Since then, because of the introduction of a radio telephone reporting scheme, instead of a form-filling one, a better coverage of total bird strikes and near misses has been achieved (Caithness, 1969). At present reports of strikes and near misses from all over the country are sent to the National Bird Hazard Committee, which then makes these reports and summaries regularly available to authorities concerned.

1.7 Christchurch Airport, problem and aim of study

The bird hazard problem at Christchurch Airport is significant for 9.9 per cent of the total reported strikes and near misses in New Zealand from June, 1965 to March, 1970 occurred on this airfield (Reports of bird strikes and near misses, Bird Hazard Committee, Department of Civil Aviation). These can be expected to continue because: (a) the airfield supports a large number of pasture feeding bird species (due to abundance of food) that are either residents or come from nearby roosts or breeding sites, (b) it is surrounded by farmlands that from time to time attract large flocks of birds either during cultivation or after harvesting; and, (c) it is situated on the diurnal flight paths used by large bird populations. In future the problem is expected to intensify because of increased flight frequency and the increasing use of faster and more vulnerable aircraft.

The aim of this study was to determine the relationship between birds and their food, with a view to developing an ecological basis for reducing the bird hazard to aircraft on this airfield.

2. THE STUDY AREA AND EXPERIMENTAL PLOTS

2.1 The study area

2.1A Location, substratum, environs, ground cover and climate

Christchurch International Airport is situated at Latitude 43° 29' S, Longitude 172° 32' E, 118 feet above sea level (Fig. 3). It is located to the north west of the city proper and nearly seven miles from the city centre. The airfield has been constructed on an old alluvial bed of the Waimakariri River which at present flows three miles to the north. Pegasus Bay is approximately ten miles to the east.

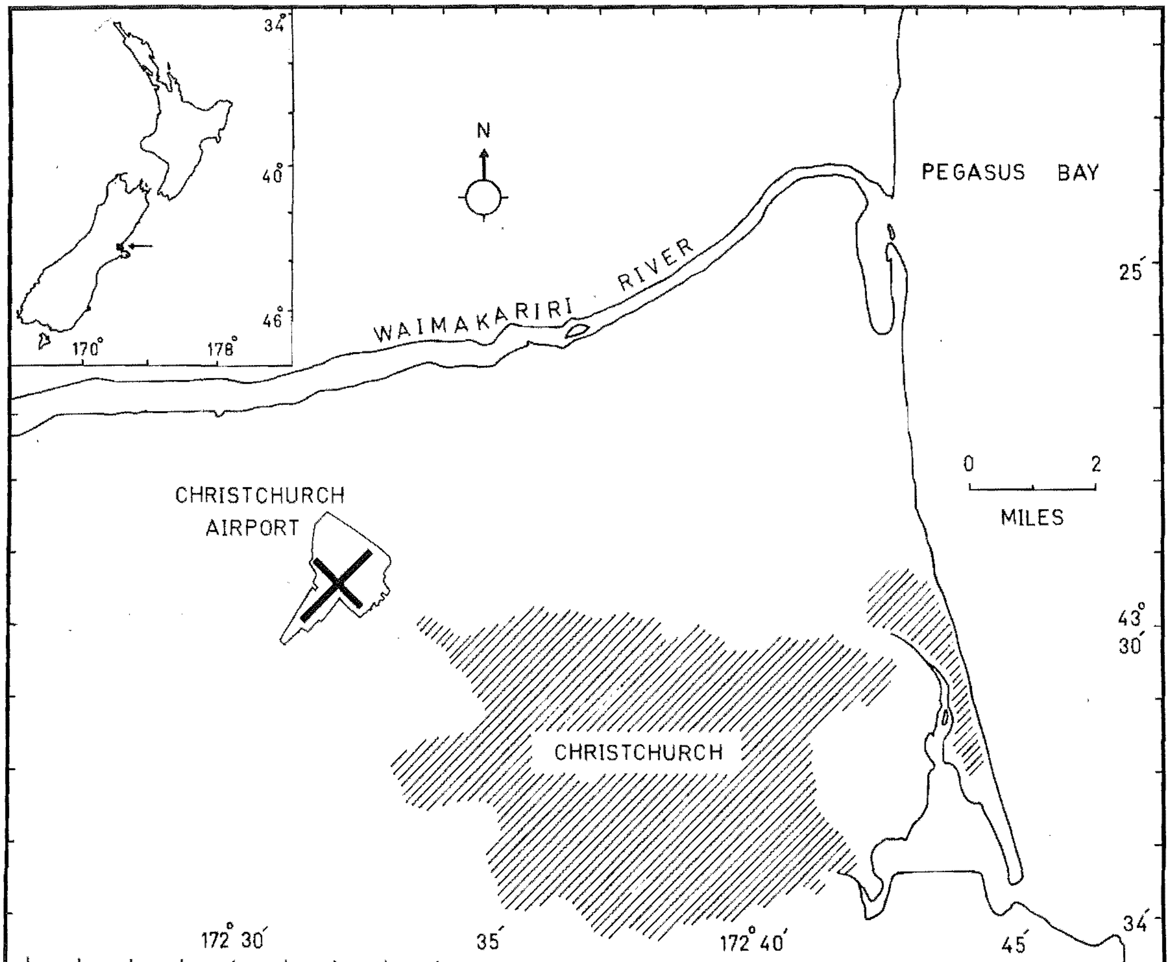
The substratum of the airfield is representative of river flats with weak-structured sandy loam top soil and sub-surface gravel. Among the non-cultivated pasture, gravel is exposed at places or is present within a few inches of the top.

Most of the airfield is surrounded by agricultural fields, farmlands or golf courses but part of the western side is uncultivated pasture. Tall trees, mostly Pine (*Pinus radiata*), form part of the northern boundary and scattered stands are also present on the surrounding farmlands (Fig. 4).

Most of the agricultural land within the airport's boundaries is on lease; the remainder forms the Airport Authority's Farm, which is mostly used for hay cultivation and stock feeding.

The main runway, 8,000 feet long and 150 feet wide, is oriented N.E.-S.W., and the subsidiary runway, 5,700 feet long and 150 feet wide, is oriented N.W.-S.E. Various taxiways accompany both runways.

The land between Harewood Golf Course and the operational boundary of the northern end of the main runway is uncultivated at present, though stock are kept there during part of the year. The land on the south and south east of the airfield is



34°
40°
46°
170°
178°
N
PEGASUS BAY
WAIMAKARIRI RIVER
25′
0 2
MILES
CHRISTCHURCH
AIRPORT
43°
30′
CHRISTCHURCH
172° 30′
35′
172° 40′
45′
34′

Figure 3

Location of Christchurch International Airport.

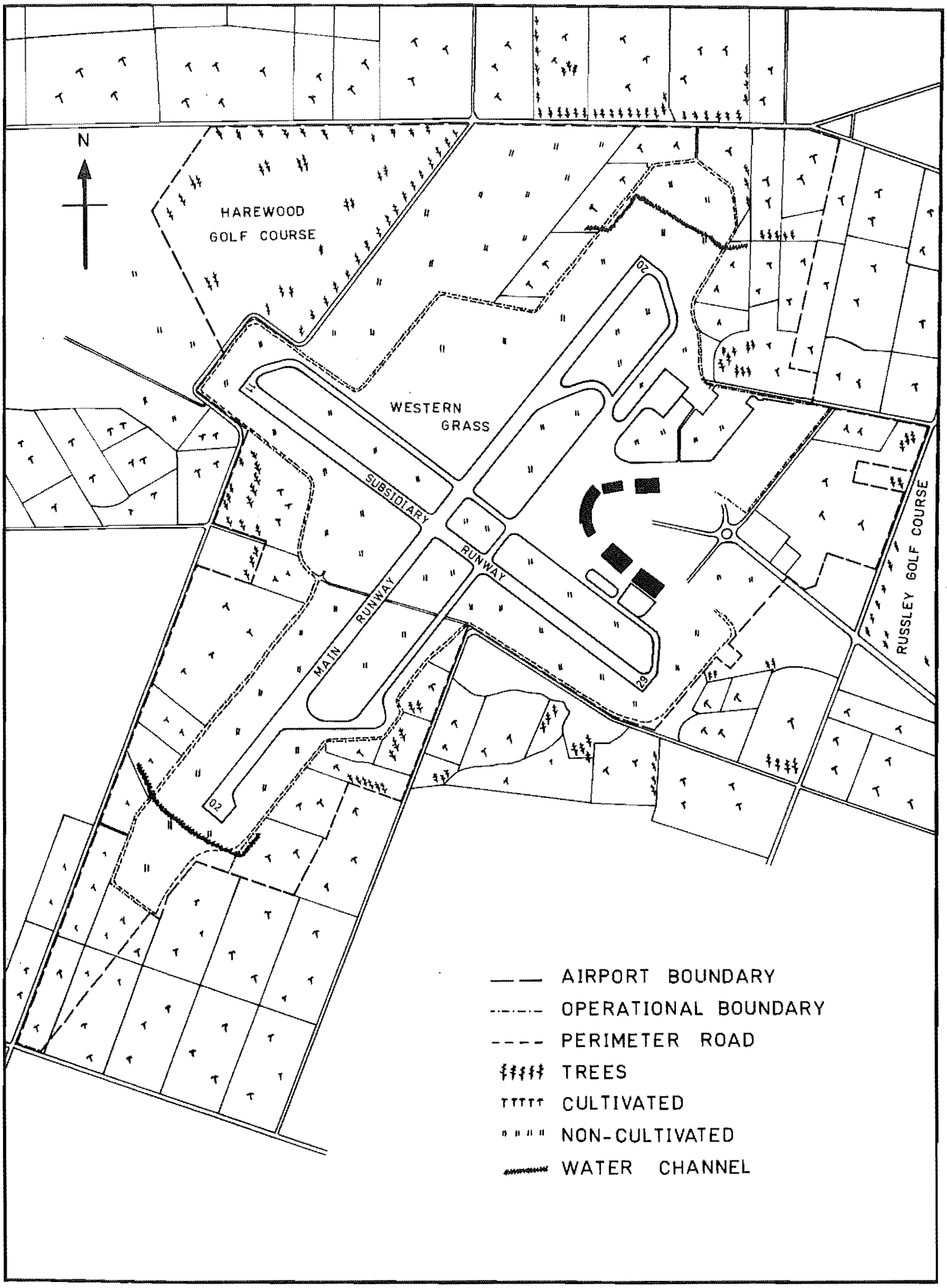

N
HAREWOOD
GOLF COURSE
WESTERN
GRASS
SUBSIDIARY
RUNWAY
MAIN
RUNWAY
RUSSLEY GOLF COURSE
20
11
29
02
AIRPORT BOUNDARY
OPERATIONAL BOUNDARY
PERIMETER ROAD
TREES
CULTIVATED
NON-CULTIVATED
WATER CHANNEL

Figure 4

Christchurch International Airport and its environs showing land use in the area.

used for mixed farming.

The area within the perimeter road and the operational boundary is well levelled and maintained in permanent grass cover consisting mainly of the following plant species:

Family Papilionaceae

Trifolium arvense
______ *pratense*
______ *dubium*
______ *repens*
______ *subterraneum*
Vicia sp.
Ulex euroaeus
Cytisus scoparius

Family Gramineae

Agrostis tenuis
Lolium multiflorum
Notodanthonia setifolia
Hordeum murinum
Stipa sp.
Poa sp.
Anthoxanthum odoratum
Aira caryophyllea
Vulpia sp.

Family Compositae

Achillea millefolium
Crepis capillaris
Taraxacum officinale
Helminthia sp.

Family Geraniaceae

Geranium molle
Erodium cicutarium

Family Polygonaceae

Polygonum sp.

Rumex ocetosella

Family Malvaceae

Malva neglecta

Family Cruciferae

Cardamine flexuosa ?

Family Plantaginaceae

Plantago lanceolata

Family Chenopodiaceae

Chenopodium album

Family Scrophulariaceae

Veronica sp.

Family Boraginaceae

Echium vulgare

Family Orobanchaceae

Orobanche minor

Family Caryophyllaceae

Stellaria media

Family Oxalidaceae

Oxalis sp.

Family Bryaceae

Bryum truncorum ?

Family Polytrichaceae

Polytrichum sp.

Family Pottiaceae

<u>Tortula</u> sp.

The grassed area (known as Western Grass), west of the northern portion of the main runway is maintained for the use of light aircraft. Part of the approaches to the main runway are in lucerne (<u>Medicago</u> sp.) cultivation while those to the subsidiary runway have permanent sparse ground cover.

Two open water channels run west to east on the northern and southern end of the main runway.

The semi-crescentic terminal building with the Airport Traffic Control Tower, the associated hangars, workshops and the taxying bay are situated in the angle of northern end of the main runway and the eastern end of the subsidiary runway.

Climatic data (for 1968 and 1969) obtained from the Christchurch Airport Meteorological Station is shown in Figure 5. Local weather conditions are affected by predominant south-westerlies, frequent north easterlies and occasional warm Föhn north-westerly winds, the latter occurring especially during spring and summer. These wind currents produce a mosaic of local climates during unsettled weather conditions.

Summer is generally warm with occasional temperatures in excess of 80°F, rarely exceeding 90°F. Winter is cold, being characterised by frequent frosts that follow calm and clear nights, mornings are usually clear after these frosts. Hail and occasional snow are experienced during winter, but snow very rarely stays on the ground more than a few hours. Maximum rain is experienced during the period April to June and October to January while sporadic precipitation is experienced during the rest of the year.

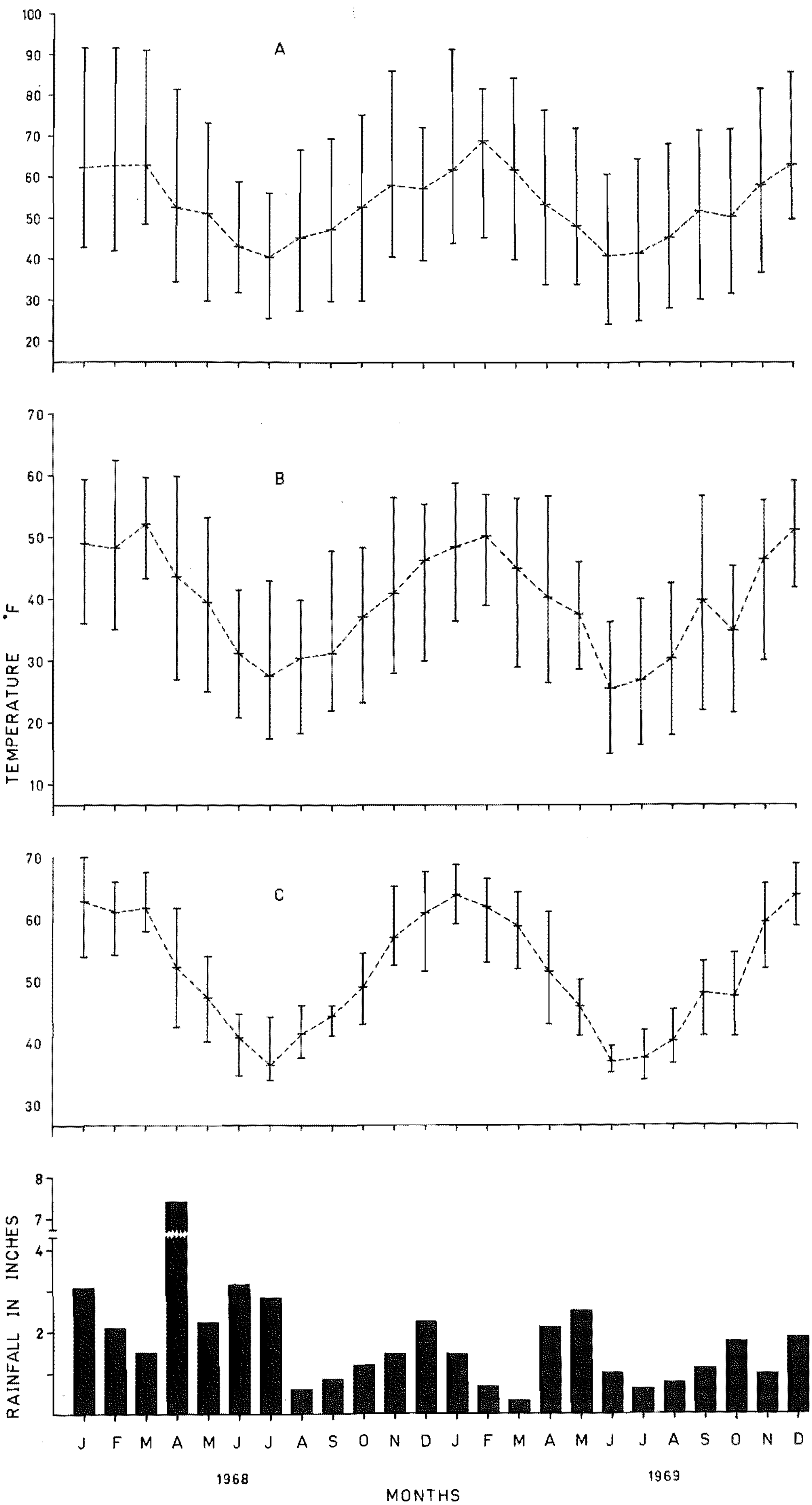

A
B
C
TEMPERATURE °F
RAINFALL IN INCHES
J F M A M J J A S O N D J F M A M J J A S O N D
1968
1969
MONTHS

Figure 5

Meteorological data for Christchurch International Airport. Monthly means of the temperature data are connected by the dotted lines; monthly maximum and minimum temperatures are represented by the upper and lower limits respectively.

Key to temperature graphs:

A.	Temperature (in the air)	(at 0900 hours)
B.	Ground temperature	(" " ")
C.	Soil temperature at 4"	(" " ")

2.2 Experimental plots in the study area

2.2A Location and experimental design

Before selecting experimental plots for detailed sampling, preliminary observations were made of birds' feeding activities on the airfield. It was noted that birds had no preference for specific areas on the airfield pasture. Since it could reasonably be expected that the different parts of the pasture might have different microclimates and thus varied faunal distribution, four experimental sites (A, B, C and D) were selected (Fig. 6). These sites were then sampled to make sure the fauna and flora therein was representative of the whole area and not merely an artifact of extreme local conditions.

Plot A was situated in the pasture at the south east end of the subsidiary runway. It had a loose sandy soil, with sparse ground cover and sub-surface gravel reaching to within four to five inches of the surface. Plot B was located at the north eastern end of the main runway and had a sandy loam soil with thick ground cover; sub-surface gravel reached to within three inches of the surface. Plot C at the north-west end of the subsidiary runway had a thick mat of grass, beneath which was a thin layer of sandy loam soil overlying sub-surface gravel. Plot D on the western pasture at the southern end of the main runway had a thick soil layer containing more clay than other areas. The ground cover was thick and sub-surface gravel at places was present within three inches of the surface.

Access to plots A and D was relatively easy via the perimeter road, but access to plots B and C required crossing the taxiways and necessitated permission from the airport traffic control.

The experimental plots were 100 sq. yds in area and were divided into five sections, one each for soil sampling, pit

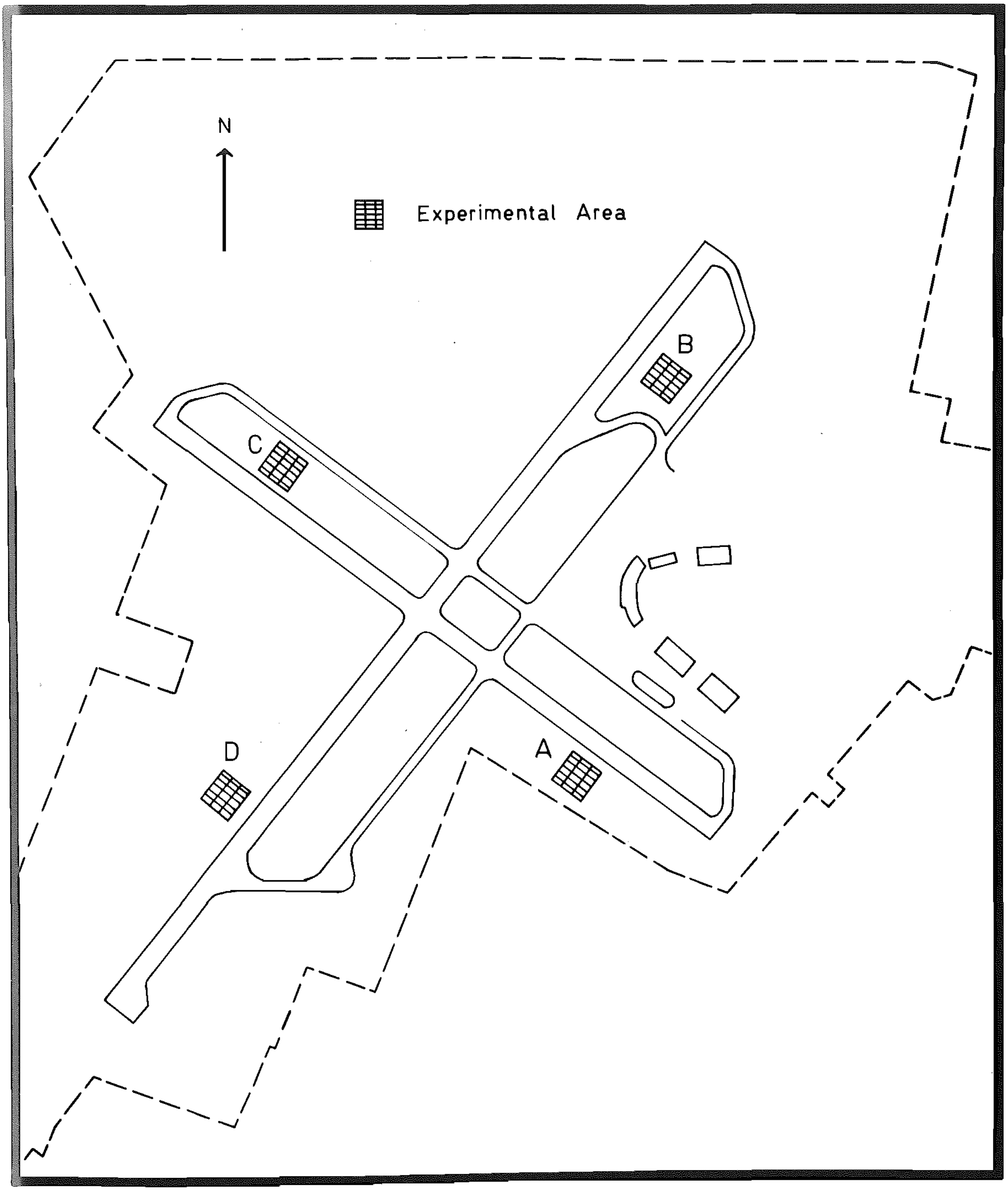
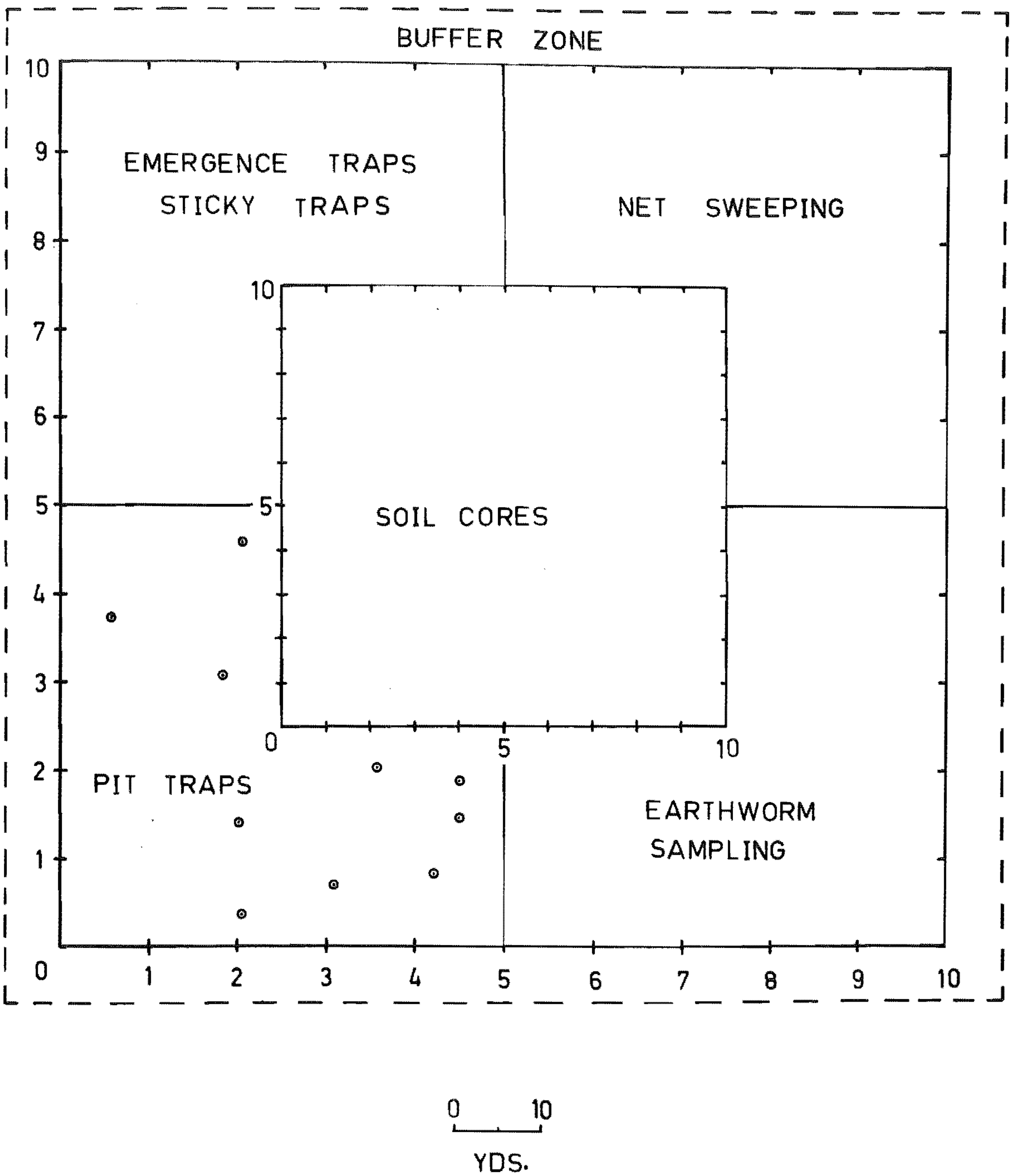

N
Experimental Area
A
B
C
D

Figure 6

Location of experimental plots (A - D) on the airfield pasture.



BUFFER ZONE
EMERGENCE TRAPS
STICKY TRAPS
NET SWEEPING
SOIL CORES
PIT TRAPS
EARTHWORM SAMPLING
0 1 2 3 4 5 6 7 8 9 10
0 5 10
0 10
YDS.

Figure 7

Diagram of an experimental plot showing sampling design.

trapping, earthworm sampling, ground sweeping with insect netting and for emergence trapping (Fig. 7).

3. METHODS

3.1 Introduction

Preliminary investigations indicated that the presence of major bird species at Christchurch Airport was determined largely by the availability of invertebrate food. Hence ecological studies of these invertebrates were undertaken, with special emphasis being placed on their availability to birds, abundance, seasonal activity and life cycles.

The selection of invertebrate sampling methods and the sampling design was influenced by the concept of prey availability to birds. Seasonal abundance of prey species on the airfield pasture was determined on the basis of their occurrence on or just below the surface. In most cases estimates of soil-inhabiting animals were made to a maximum depth of 3.5". The abundance of food species at and above this depth seems to influence bird predation (also see Section, Available Food).

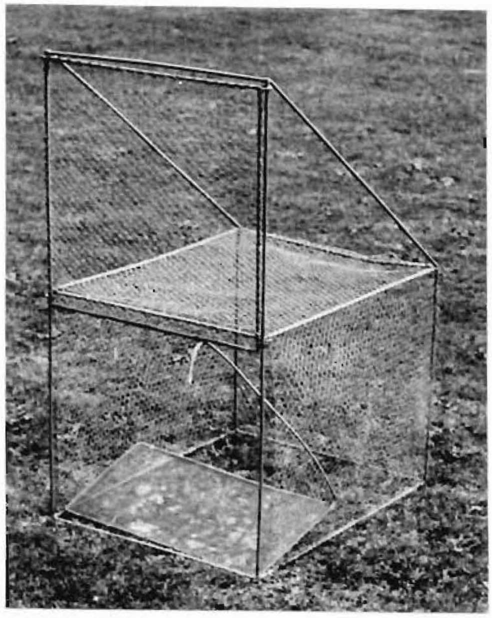
General methods of study are described below and specific techniques are detailed in later sections.

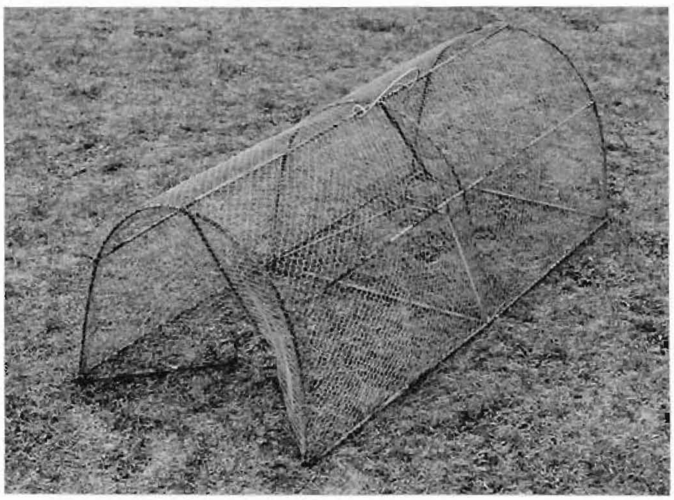
3.2 Bird samples

Bird samples were collected for food analysis by trapping and shooting. Three types of traps were used, all based on Hollom's (1950) design: (a) drop door trap; (b) sparrow trap; and, (c) modified house trap. Each of these traps was made of 0.5" mesh chicken netting on a framework of iron rods.

The drop door trap (Plate 1) measured 24 x 18 x 18" and was sprung when a bird landed on a treadle-type trigger.

The sparrow trap (Plate 2) was of hemispherical shape and comprised two chambers with funnel entrances to each. The first funnel extended into the front chamber at ground





Bird traps used in this study

Plate 1

Drop door trap

Plate 2

Sparrow trap

Plate 3

Modified house trap

level while the second was slightly raised from the ground and provided with a gauze floor. Birds were removed through a 6 x 6" door in the back of the second chamber. The trap measured 48" long, 20" wide at the base and had a maximum height of 16". The funnels projected 8" into the chamber, measuring 4 x 3" at their inner entrance.

The modified house trap (Plate 3) was of rectangular construction, measuring 48 x 36 x 30" with four funnel shaped entrances on each side. A 12 x 6" door was provided on the top for removing birds. The funnels extended 12" inside the trap at an angle, with 11 x 11" outer entrances and 7 x 6" inner ones.

All the traps were baited with wheat and firmly pegged down to withstand high winds.

Although live-trapping was a successful method of obtaining small numbers of Magpies, Starlings and Sparrows, several difficulties were encountered in obtaining the large number required for food analysis. A large number of traps had to be used and each of these required frequent checking. Captured birds had to be removed from the traps as soon as possible or the gut contents were digested and/or obscured by ingested bait. Carnivorous birds feeding on the pasture were reluctant to take the baits while on other occasions they were disturbed from the vicinity of the traps by either plane movement or by airport vehicles.

Most of the bird samples were obtained by shooting with 410 and 12 gauge shotguns. Freshly shot birds were treated with 10% formalin, which was sprayed down the oesophagus to prevent further food digestion. The carcasses were taken back to the laboratory where the gut was removed and the contents washed through an 0.00708" (180 micron) sieve before examination. Identifiable animal and plant food was sorted out into major groups and preserved in 70% alcohol before storing for later examination and closer identification.

3.3 Invertebrate sampling

The invertebrate population was so diverse that no single sampling method could be considered adequate. Consequently various methods had to be used. To assess diversity and abundance of invertebrates in the experimental plots a fortnightly sampling programme was undertaken. The methods used are outlined below.

3.3A Soil samples

I. Insects

On every occasion ten soil cores from each experimental plot were taken. Each core was 2.5" in diameter and approximately 3.5" deep (surface area 4.9 square inches and volume 17.15 cubic inches). The sample site was determined by reference to a table of random numbers (Fisher and Yates, 1957). The soil cores were taken from the plot by using a field corer (Plate 4). Each core was kept separately in a numbered plastic bag to protect it from weather, contamination or loss of organisms, and desiccation.

In the laboratory each core was gently crumbled in a plastic tray and the visible invertebrates separated. Crumbled soil was then gently washed with water through a set of sieves (Plate 5) with apertures of 0.1875, 0.08098, 0.03948 and 0.00708" (4762, 2057, 1003 and 180 microns respectively). Each sieve was then thoroughly examined under a table lamp and the animals present were collected. The plant material from the largest mesh sieve was separately examined and then placed in Tullgren funnels to collect any remaining forms. The extracting unit (Plate 6) consisted of five funnels arranged in a row. Collecting bottles containing 70% alcohol were provided at the base of each funnel.


ENDECOTTS
(FILTERS) LTD.
LONDON, ENGLAND.

Plate 4

Field corer used for soil sampling (after Cole-
man, 1968).

Plate 5

A set of sieves for separating soil invertebrates.

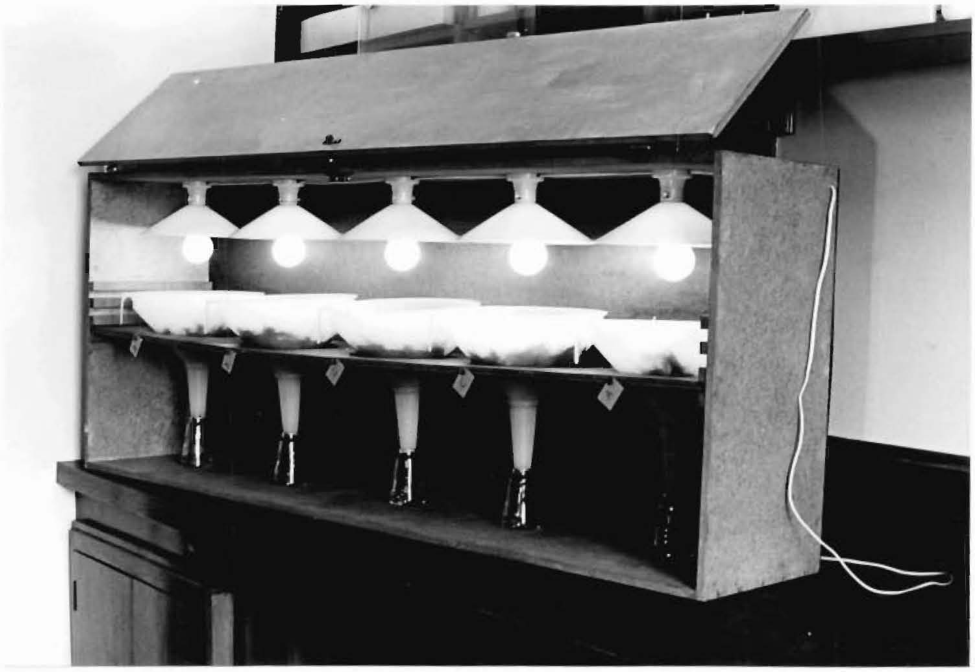


Plate 6

Tullgren type extraction apparatus used for extracting soil invertebrates from the litter.

Plate 7

Method of sampling earthworms on the airfield pasture.

II. Earthworms

Earthworm (Lumbricidae) numbers were estimated by a combination of two methods; potassium permanganate extraction and hand-sorting. To one gallon of water half an ounce of potassium permanganate was added and the solution applied to one square yard. Each sample consisted of four sub-samples, one from each experimental plot. Earthworms brought to the surface by this method were collected in bottles containing 4% formalin. Following surface collection, the area was dug to a depth of 3.5" and the soil hand-sorted for the remaining worms (Plate 7).

3.3B Pit traps

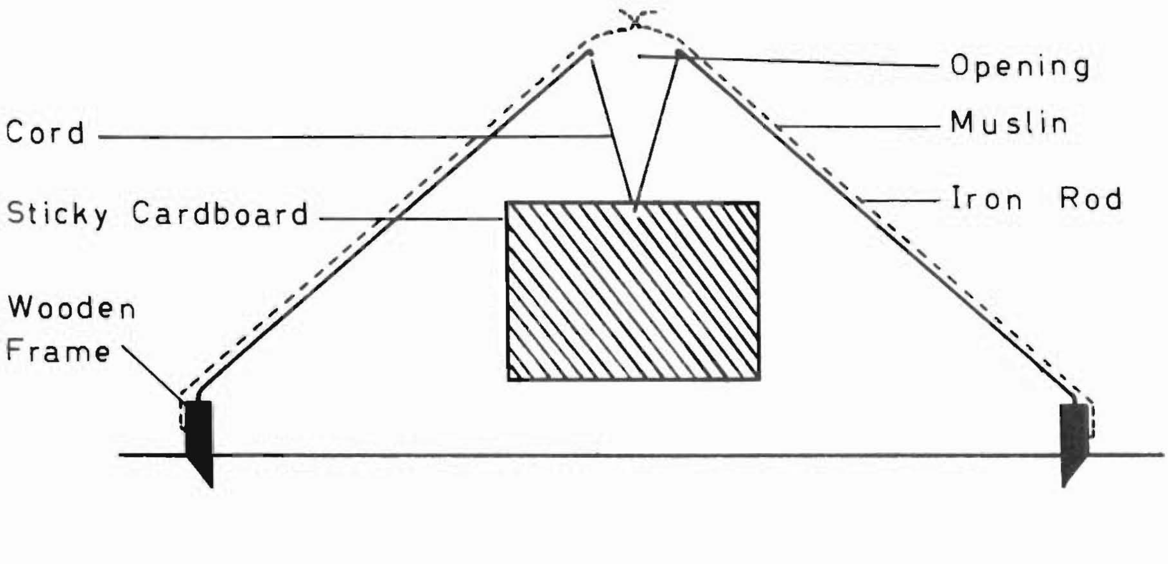
In each experimental plot ten pit traps were randomly placed at ground level (Plate 8). Each trap was made of two closely-fitting polythene tubes, the outer tube was 6.5" long and 2.559" across and the inner was 5" long and 2.401" across. The inner tube with a gauze base of narrow mesh, fitted closely in the outer. At 1.5" above the bottom of the outer tube a stopper was provided to hold the top of the inner tube at ground level. The gauze base of the inner tube allowed rain water through to the 1.5" space left between the base and the ground. Collections were made weekly.

3.3C Net sweeping

Ground sweeping with an insect net was carried out to collect forms that are found amongst the vegetation. The ordinary round insect net was slightly modified by providing a 9" straight base at one side. Four sweeps of one yard each gave an approximate coverage of one square yard.

3.3D Emergence traps

For collecting emerging insects during spring and summer



EMERGENCE TRAP

Plate 8

One of the pit traps on the experimental plot used to collect surface dwelling invertebrates (trap designed by K.W. Duncan).

Figure 8

Sectional diagram of an emergence trap.

two pyramid shaped emergence traps were used on each experimental plot. Each trap was covered with muslin cloth and measured one square yard at the base and two feet high at the centre (Fig. 8). An 18 x 12" piece of cardboard coated with "Davis 437" glue on both sides was suspended vertically inside each trap as a collecting device.

3.3E Sticky traps

One square foot pieces of brown cardboard with "Davis 437" glue were used for collecting some surface dwelling forms. The cardboard pieces were nailed horizontally at ground level on experimental plots (Plate 9) with the main objective of collecting information on the start of activity of insect forms; especially grasshoppers and crickets. The insects were collected only during dry weather because the glue was effective under such conditions; rain, however, rendered it ineffective.

3.3F Light trap

During spring and summer a kerosene burner light trap (Plate 10) was occasionally used to collect nocturnal insects. The trap was 12 x 12" at the base and 24" high. Entrances to the light source were provided by louvre glass windows. The metal funnel below the light source led to a collecting jar affixed to the base of the funnel.

3.3G Direct counts

The numbers of adult grasshoppers and crickets were estimated by a direct count method. A one square yard wooden frame was carefully placed on the pasture, the area was then disturbed and the grasshoppers and crickets jumping out of the quadrat were counted separately.

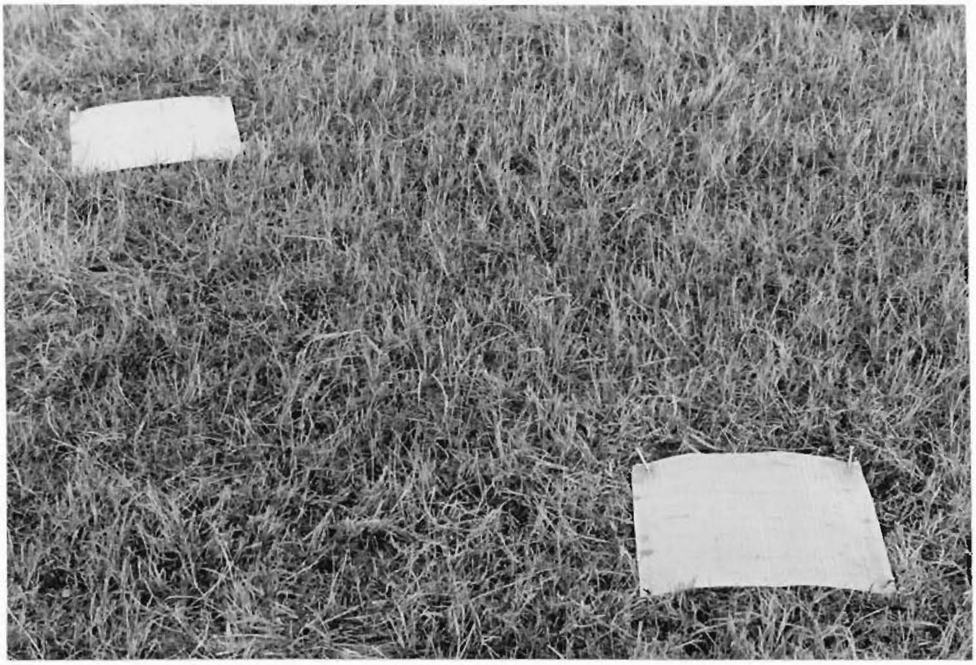


Plate 9

Cardboard sticky traps on the experimental plot.

Plate 10

A kerosene burner light trap used to collect nocturnal insects.

3.4 Preservation

The adult insects and arachnids from field samples were preserved in an arthropod fixative (70% alcohol, 12 parts and Glycerol and Glacial Acetic Acid, 1 part each), insect larvae were kept in Van Emden's fixative (Lewis and Taylor, 1967) and earthworms were preserved in 4% formalin.

3.5 Measurements

The British system of measurement is used in New Zealand for aviation purposes, and due to affinity of this work with aviation the same system has been used. However, in instances like micro-organism experiments (see insecticide trial) the use of the metric system was necessary.

4. BIRDS AT CHRISTCHURCH AIRPORT

4.1 Introduction

The presence of birds and their movements in the area were noted by regular observations from the Airport Control Tower and also by moving around the airfield along various roads. This information was supplemented by report cards of bird sightings filled in by the Civil Aviation Administration officials.

The bird fauna was dominated by common pasture feeders and scavenging birds that utilized the area mostly for feeding. Although no major migratory routes cross the airfield, it does lie in the line of flight of birds moving to and from their nocturnal roosts each day.

4.2 Species composition

The following species were observed at the airfield during 1968-69.

Family Laridae

- Black-backed Gull — Larus dominicanus
- Black-billed Gull — Larus bulleri
- Red-billed Gull — Larus novaehollandiae

Family Ardeidae

- White-faced Heron — Notophoyx novaehollandiae

Family Anatidae

- Mallard — Anas platyrhynchos

Family Charadriidae

- Banded Dotterel — Charadrius bicinctus

Family Cracticidae

- White-backed Magpie — Gymnorhina hypoleuca

Family Corvidae		
	Rook	_Corvus frugilegus_
Family Columbidae		
	Pigeon	_Columba livia_
Family Sturnidae		
	Starling	_Sturnus vulgaris_
Family Accipitridae		
	Harrier Hawk	_Circus approximans_
Family Turdidae		
	Blackbird	_Turdus merula_
	Thrush	_Turdus ericetorum_
Family Alaudidae		
	Skylark	_Alauda arvensis_
Family Motacillidae		
	New Zealand Pipit	_Anthus novaeseelandiae_
Family Ploceidae		
	House Sparrow	_Passer domesticus_
Family Fringillidae		
	Greenfinch	_Chloris chloris_
	Goldfinch	_Carduelis carduelis_
	Yellowhammer	_Emberiza citrinella_

4.3 Resident and transient species

Of the above nineteen species, Magpies, Starlings, Harrier Hawks, Thrushes, Blackbirds, Skylarks, Pipits and small passerines were residents. These birds generally utilized the airport establishment, trees, hedges and shrubs for roosting, nesting and feeding. The gulls, ducks, Rooks,

Table 1: Seasonal abundance of birds (gulls, Starling, Magpie and small passerines) at Christchurch Airport during 1968-69

	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of ½ hourly observations	66	67	68	64	58	64	61	63	68	68	59	64
Number of birds seen in each month	4170	3880	5015	13445	18225	16858	11250	11980	16690	8225	4061	4217
Average number per observation	63.2	57.9	73.7	210.1	314.2	263.4	184.4	190.1	245.4	120.9	68.8	65.9

Table 2: Seasonal abundance of gulls (*Larus dominicanus* and *L. bulleri*) at Christchurch Airport during 1968-69

	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of ½ hourly observations	66	67	68	64	58	64	61	63	68	68	59	64
Number of times present	7	14	17	37	38	41	37	35	12	7	6	7
Percentage of occurrence	16.6	20.8	25.0	57.8	65.5	64.0	60.6	55.5	17.6	10.2	10.1	10.9
Total number of birds	60	165	610	1875	1965	2250	1890	1750	440	40	56	69
Average flock size	8.6	11.8	35.9	50.7	51.7	54.9	51.1	50.0	36.7	5.7	9.3	9.8

Pigeons, White-faced Herons and Banded Dotterels were seasonal transients. Some species, such as Starlings and small passerines, fall into both categories because resident populations were maintained throughout the year while large seasonal flocks also appeared. For the latter reason, the density of some resident species occasionally showed a dramatic increase.

4.4 Seasonal trends in bird numbers

The numbers of birds varied with the season, a maximum being present from April to October, while numbers were lowest during the period November to March (see Table 1). The data in the table are based on the total number of gulls, Starlings, Magpies and small passerines observed during respective months. Other species are mentioned later in the section.

Birds were most numerous outside their breeding season, when gregariousness was common on the feeding grounds. Lower counts coincided with the breeding season, a period when breeding populations were dispersed away from the airfield for nesting activities.

The seasonal trend in the number of gulls, Starlings, agpies and small passerines is recorded in Tables 2, 3, 4 and 5. Gull flocks of 30 to 60 birds were present from late March to early September, although a few birds (up to ten birds) were seen outside this period (see Table 2). Of the three gull species, the Black-backed Gull (Larus dominicanus) was most common, whilst occasional flocks of Black-billed Gulls (L. bulleri) and rarely Red-billed Gulls (L. novaehollandiae) were observed.

Gulls arrived on the airfield at about sunrise, either as a flock or in small numbers, reaching a maximum within an hour. When on the airfield they foraged on the pasture or along the edges of the runways and taxiways, and if undisturbed, rested

Table 5: Seasonal abundance of small passerines (*Passer domesticus*, *Chloris chloris* and *Carduelis carduelis*) at Christchurch Airport during 1968-69

	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of ½ hourly observations	66	67	68	64	58	64	61	63	68	68	59	64
Number of times present	13	8	13	12	13	13	4	7	13	13	21	20
Percentage of occurrence	19.6	11.9	19.1	18.7	22.4	20.4	6.5	11.1	19.1	19.1	35.5	31.2
Total number of birds	1250	830	1350	240	330	315	95	200	410	410	910	1970
Average flock size	96.1	103.7	103.8	20.0	25.4	24.2	23.8	28.6	31.5	31.5	43.3	98.5

Table 3: Seasonal abundance of Starling (<u>Sturnus vulgaris</u>) at Christchurch Airport during 1968-69

	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of ½ hourly observations	66	67	68	64	58	64	61	63	68	68	59	64
Number of times present	35	40	42	38	44	44	40	46	43	38	41	45
Percentage of occurrence	53.0	59.7	61.7	59.3	75.8	68.7	65.5	73.0	63.2	55.8	59.4	70.3
Total number of birds	815	1025	1525	9600	14250	12900	7850	8300	13750	4850	1515	640
Average flock size	23.3	25.6	36.3	252.6	323.9	293.2	196.3	190.4	319.8	127.6	37.0	14.2

Table 4: Seasonal abundance of Magpie (<u>Gymnorhina hypoleuca</u>) at Christchurch Airport during 1968-69

	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of ½ hourly observations	66	67	68	64	58	64	61	63	68	68	59	64
Number of times present	48	48	40	44	44	40	39	39	42	51	37	35
Percentage of occurrence	72.7	71.6	58.8	68.7	75.8	62.5	63.9	61.9	61.7	75.0	62.7	54.6
Total number of birds	2045	1860	1530	1730	1680	1393	1415	1730	2090	2925	1580	1535
Average number per observation	42.6	38.7	38.3	39.3	38.2	34.8	36.3	44.4	49.8	57.4	42.7	43.9

and preened between feeding bouts. These flocks left the airfield only when continuously disturbed.

The major concentrations (100 to 350) of Starlings (Sturnus vulgaris) were present from April to early October, after which the numbers were considerably reduced (see Table 3). In mid-October large flocks disappeared because of the onset of the breeding season. This situation continued until late March when large post-breeding flocks reappeared.

Magpies (Gymnorhina hypoleuca) were common but less abundant than the previously mentioned species, and maintained a reasonably constant population level (of 30 to 60 birds) throughout the year (see Table 4). They roosted and bred amongst the trees around the airfield, and thus formed a resident population. Unlike some other species, they did not form large flocks, although a group of twenty to thirty birds was occasionally seen feeding on some parts of the airfield.

Small passerines, especially House Sparrows (Passer domesticus), Goldfinches (Carduelis carduelis) and Greenfinches (Chloris chloris) formed occasional flocks of 100 and over during December to March, while in other months the numbers were much smaller (see Table 5).

Pigeons (Columba livia) were present in flocks of 100 to 150 birds on the southern agricultural fields at harvesting time. They usually arrived in the morning to feed and left in the late afternoon. Their feeding was mainly concentrated on fields under wheat (Triticum sp.), oats (Avena sp.), peas (Pisum sp.) and clover (Trifolium sp.) cultivation.

Harrier Hawks (Circus approximans) were mostly seen flying or resting within the airfield area, and rarely disturbing other birds. Their numbers ranged from four to six birds, of which one pair was confined to the northern end of the airfield, while the other four were irregularly seen at the southern end.

Rooks (Corvus frugilegus) were infrequently observed during March and April. On all occasions they occurred in flocks of from ten to fifteen birds and their stay on the pasture was confined to a few hours each morning.

Ducks (Anas platyrhynchos), White-faced Herons (Notophoyx novaehollandiae) and Banded Dotterel (Charadrius bicinctus) frequented the airfield singly or in pairs during April to June. These birds were mostly observed along the two open water channels that run on the northern and southern extremities of the main runway.

Blackbirds (Turdus merula) and the Thrush (Turdus ericetorum) were seen along the southern boundary and amongst the hedges, trees and shrubs. Their numbers were similar, ranging from twelve to sixteen of each species.

The number of Yellowhammers (Emberiza citrinella) fluctuated between twenty and thirty birds. They were distributed all over the airfield, but were frequently seen along the fences and shrubs on the eastern and southern side of the airfield.

Skylarks (Alauda arvensis) and New Zealand Pipits (Anthus novaeseelandiae) were common pastural birds. Their numbers varied between 30 and 50.

4.5 Factors affecting distribution and abundance

The distribution and abundance of birds on the airfield is affected by the following factors.

4.5A Gregarious behaviour

Outside the breeding season, flocks of gulls, Starlings, small passerines and Pigeons fed on the airfield and its surroundings. The advantages of this gregarious behaviour are considered to be the increased efficiency in food-finding and decreased vulnerability to predator attacks (see Lack, 1954; Hinde, 1961; Ward, 1965). As there are no major bird predators in the area, it seems likely that the gregariousness among the above mentioned birds is associated with exploitation of food sources. Whenever areas with food supplies are recognised the birds visit them and remain there for some time before moving to other prospective feeding grounds.

Flock formation in these birds was related to the activities of the earliest arriving birds. Feeding birds acted as decoys, and could be easily detected on the open pasture by other individuals, especially when the latter were searching for food. Similar flocking behaviour in pigeons was noted by Goodwin (1967). Once these flocks were formed and the birds had had the opportunity to feed for a while, the structure and the number of individuals in the flock was maintained for most of that day.

Starlings gradually congregated seasonally on the pasture, although the number of incoming birds varied. Usually a constant inflow was maintained each day so that a flock size of 300 or more was reached within an hour. These flocks moved at random from one place to another for feeding, the direction of flight depending on the movement of the "leading birds". While the flocks were settled, a few birds in the front and periphery of the group seemed to act as sentinels, being the first to take flight when disturbed.

Starling flocks, while undisturbed, fed in the above manner, but whenever subjected to disturbance, usually broke into smaller units that circled over the airfield before settling at temporary roosting sites. Re-flocking started in much the same manner as mentioned earlier except that the birds came back in much larger numbers and the flock size was re-established in a shorter time.

Flocks of small passerines formed in much the same way as Starlings. The behaviour of the respective species flocks differed in that the small passerines spent a lot more time at one feeding place before shifting to another, while starlings kept gradually on the move.

Gull flocks on the other hand were much more sedentary in comparison to either starling or small passerine flocks. Gulls when settled spent most of the time in the same area and seldom moved to settle in another area unless disturbed from the first place.

Pigeon flocks on the harvested grain fields behaved like gull flocks. These birds spent most of their time feeding on the field that they had settled on that morning.

4.5B Territories and home ranges

During the breeding season most birds were territorial and maintained actively defended areas, while out of the breeding season they normally occupied home ranges (sensu Odum, 1962). The Magpies on the airfield showed this behaviour. Territories were strongly defended during the breeding season, when wandering gulls, Harrier Hawks and some other birds were chased from the nesting areas. Out of the breeding season they defended larger feeding territories against individuals of their own species. Members of other species feeding or flying over the area were seldom challenged.

Harrier Hawks on the airfield probably maintained home ranges because two birds (possibly a pair) were confined to the northern area while another four birds remained on the southern end of the airfield.

4.5C Movements

The local movements of Black-backed Gulls (*L. dominicanus*), Starlings (*S. vulgaris*) and Pigeons (*C. livia*) had a direct relationship to the bird concentrations in the area. These movements and the subsequent concentrations, occasionally endangered aircraft safety. Movement patterns of the above three species is outlined below.

I. Gull movements

Black-backed Gulls (L. dominicanus) had a set flight pattern about the airfield. These birds, although traditionally coastal feeders, have acquired scavenging habits and are now frequently communal feeders at various refuse dumps and cultivated fields.

Communal roosts and breeding colonies were present in the Waimakariri river bed to the north of the airfield, from which birds flew to feeding grounds in the east and south. Flights occurred throughout the year, but the size of flocks in the flights decreased during the breeding season. The daily movements to and from the roost areas X and Y are shown in Figures 9 and 10.

The major flights from the roosting area X took place towards the west of the airfield in a N.-S. direction, while minor flights in the morning headed towards the airfield. Some birds settled along the runways or taxiways while others flew southwards to either the agricultural fields or to the Islington Freezing Works in the south. During the winter mornings flocks that used the minor flight paths exhibited a direction-finding behaviour. They flew over the Harewood Golf Course and then turned southwards at a point above the main runway.

Major bird movements from the roosting area Y are not shown in Figure 9 and took place at some distance from the airfield, mainly from the roost to the Waimairi Council rubbish dump and the Belfast Freezing Works to the north-east of the airfield. Birds in the morning minor flights started as a group and then dispersed into smaller sub-groups as the flocks moved south.

The morning movements, especially along the minor flight paths, were somewhat indeterminate as the birds were probably searching for food. Evening flights towards the roosting areas were much more determinate and regular.

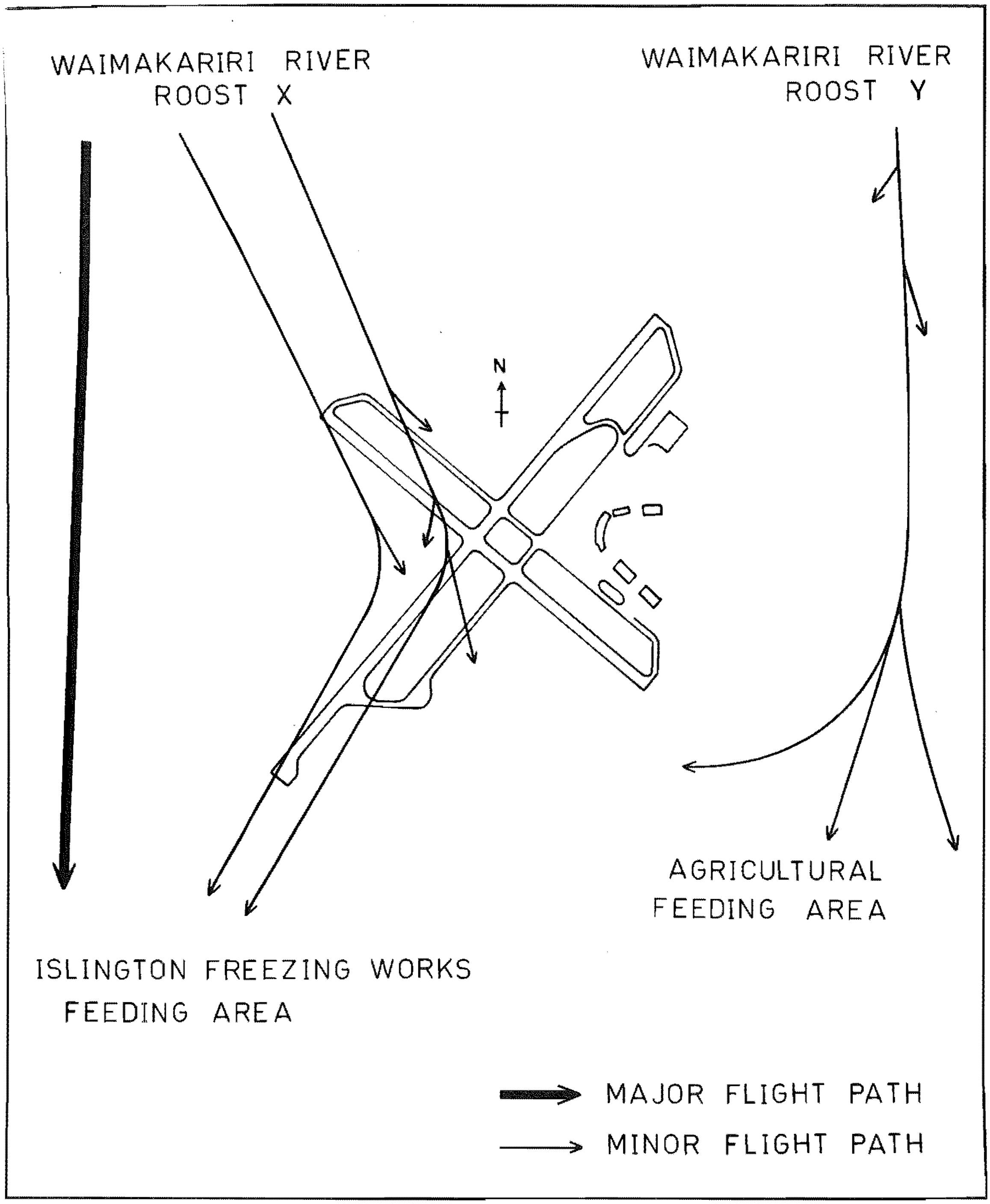

WAIMAKARIRI RIVER
ROOST X
WAIMAKARIRI RIVER
ROOST Y
N
AGRICULTURAL
FEEDING AREA
ISLINGTON FREEZING WORKS
FEEDING AREA
MAJOR FLIGHT PATH
MINOR FLIGHT PATH

Figure 9

Daily morning movement of the Black-backed Gull (*Larus dominicanus*) from nocturnal roosts to feeding grounds.

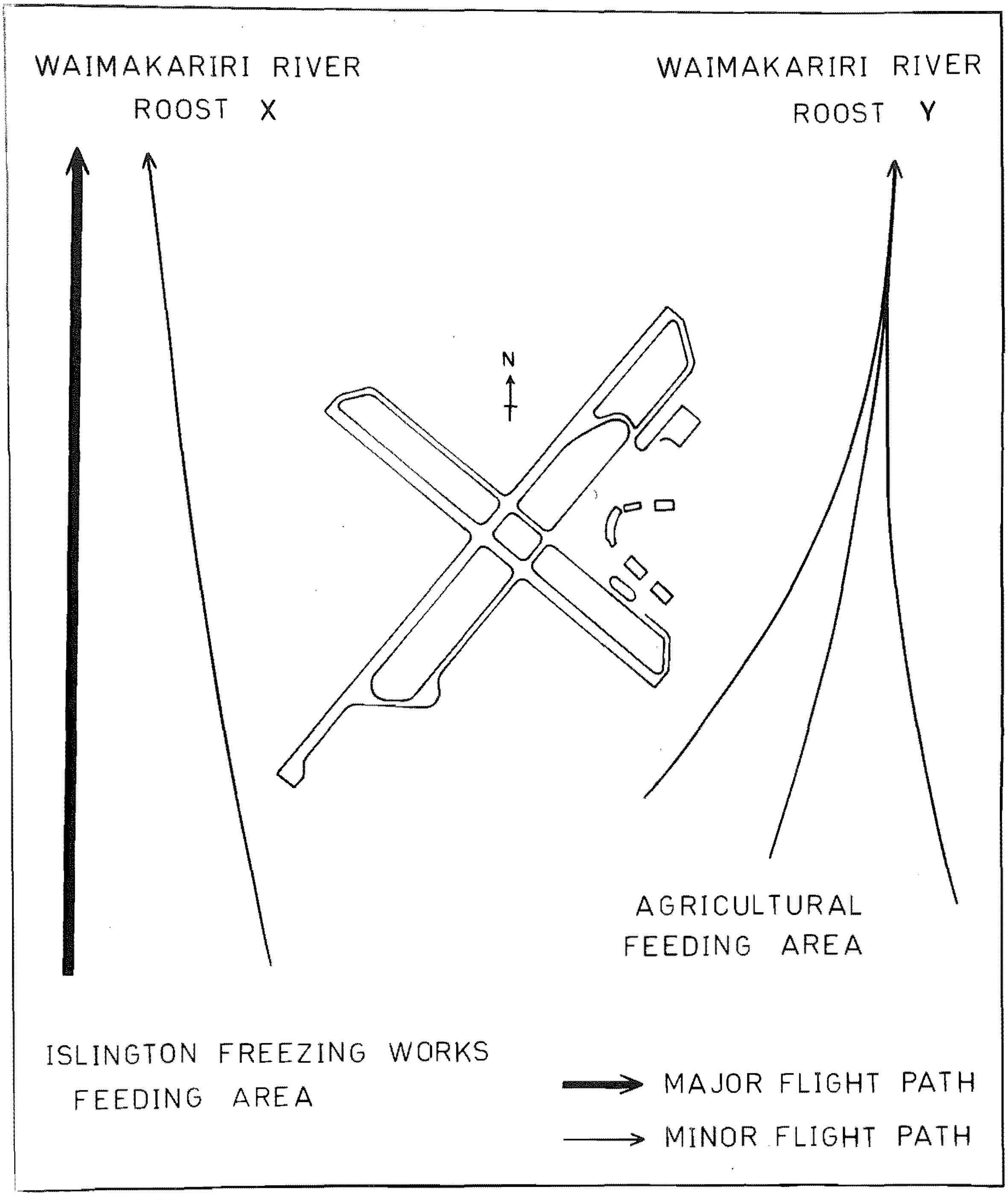

WAIMAKARIRI RIVER
ROOST X
WAIMAKARIRI RIVER
ROOST Y
N
AGRICULTURAL
FEEDING AREA
ISLINGTON FREEZING WORKS
FEEDING AREA
MAJOR FLIGHT PATH
MINOR FLIGHT PATH

Figure 10

Daily evening movement of the Black-backed Gull (*L. dominicanus*) from feeding grounds to nocturnal roosts.

II. Starling movements

Starling (*S. vulgaris*) movements were only noticeable during April to early October when the birds formed large flocks on the airfield. They arrived just after sunrise from their night roosts and showed more direct flight towards the pasture than did gulls (see Fig. 11).

Once a flock had been formed, it moved over the airfield pasture intermittently from one place to another. After feeding, these flocks dispersed into smaller units that flew back to their night roosts, probably in the urban area and amongst Pine trees (*Pinus* sp.) on the nearby farmlands.

III. Pigeon movements

Daily Pigeon (*C. livia*) movements took place in E.-W. and W.-E. directions (see Fig. 12). These flights were observed throughout the day but were most frequent in the morning and afternoon when flocks of ten to twenty birds flew across the airfield. Seasonal movements, on the other hand, were confined to the southern agricultural cropping area during and after harvesting time. Birds believed to be roosting in urban areas and in the hills south of Christchurch city flew to the cropping area and back again each day.

4.6 Food and climate

Food sources are of great importance in attracting birds to habitats. The airfield pastures harbour a variety of invertebrate forms and plant seeds that constitute bird food. The availability of such food is further dependent upon climatic factors. Details of these aspects are discussed in Section 5.

4.7 Discussion

Christchurch Airport has a persistent danger from resident

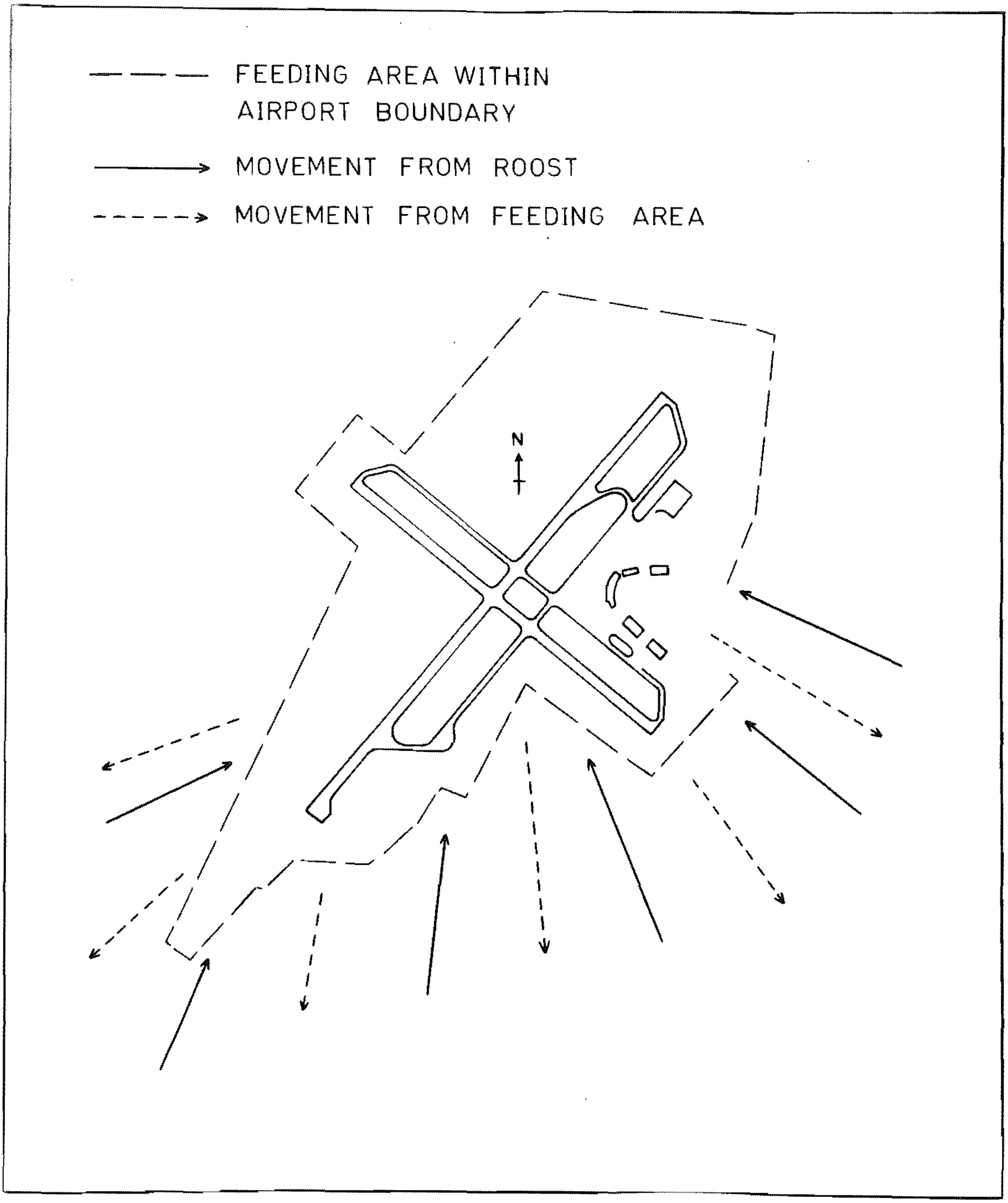

FEEDING AREA WITHIN AIRPORT BOUNDARY
MOVEMENT FROM ROOST
MOVEMENT FROM FEEDING AREA
N

Figure 11

Daily movements of Starlings (*Sturnus vulgaris*) during the flocking period.

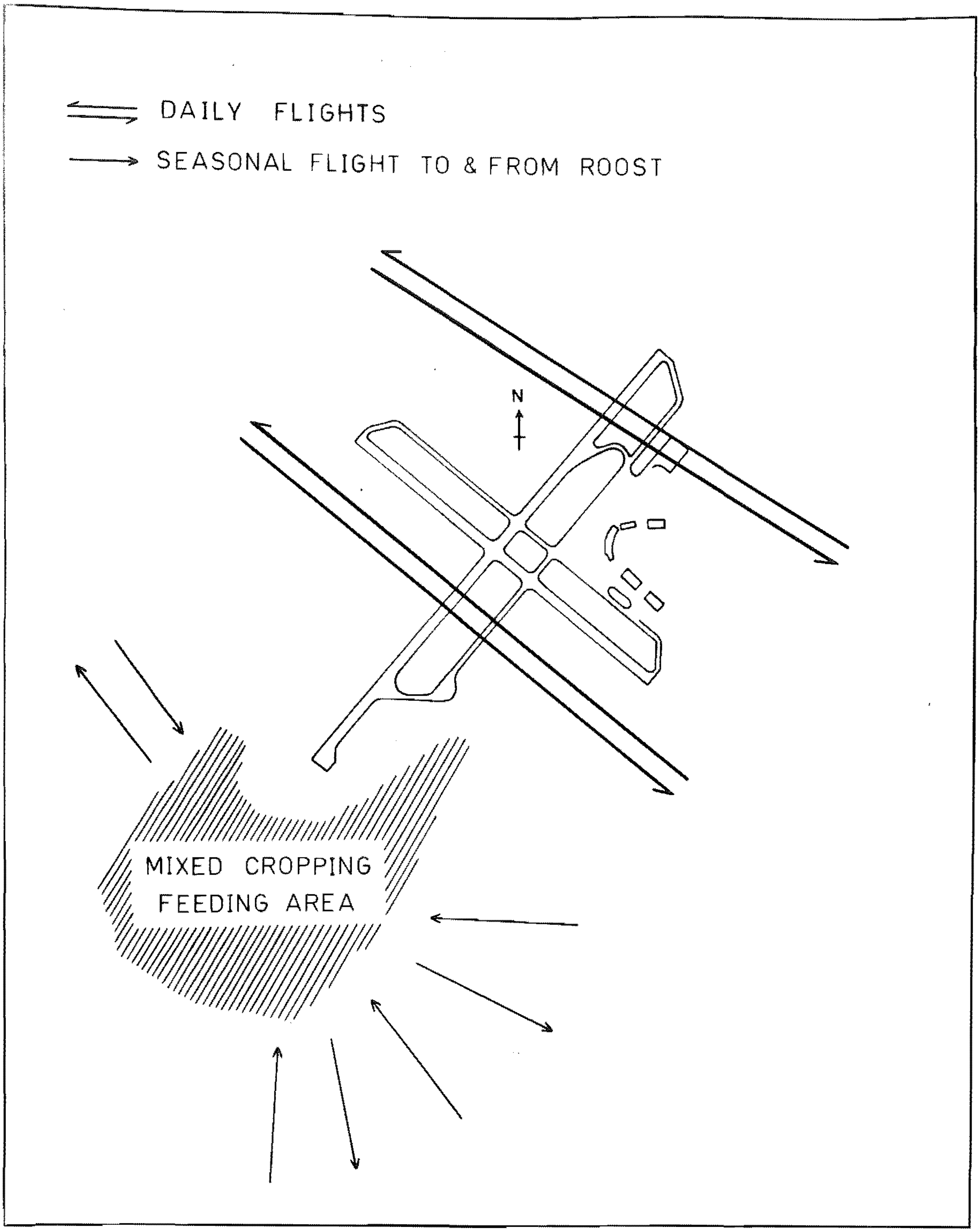

DAILY FLIGHTS
SEASONAL FLIGHT TO & FROM ROOST
N
MIXED CROPPING
FEEDING AREA

Figure 12

Daily flights and seasonal movements of Pigeons (*Columba livia*).

and transient bird populations. Of the nineteen species present at the airport, nine (three species of gulls, Starlings, Magpies, Pigeons, Harrier Hawks, Mallard and White-faced Herons) are regarded as serious hazards, because of their size or numbers, while flocks of Sparrows, Goldfinches and Greenfinches constitute a lesser hazard. Other species that use the airfield are considered as potentially hazardous.

The hazardous bird species on some other New Zealand airfields are shown in Table 6.

Table 6: Hazardous birds on various New Zealand airfields

Airfields	Birds					
	Gulls	Waders	Waterfowl	Starlings	Magpies	Others
Whangarei	X	X	-	X	-	X
Auckland	X	X	X	-	-	-
Tauranga	X	-	-	-	-	-
Gisborne	X	-	-	X	-	X
Napier (Hawke's Bay)	X	-	X	X	-	-
Ohakea	-	-	-	X	X	-
Wellington	X	-	-	X	-	-
Nelson	X	-	-	X	-	-
Christchurch	X	-	-	X	X	X
Dunedin (Momona)	X	-	-	X	-	X
Invercargill	X	X	-	X	-	X

This information is summarized from various reports of surveys conducted by the New Zealand Wildlife Service. Gulls and Starlings occur on all these airfields, whereas other birds occur sporadically at different localities. The greater variety of hazardous birds at Christchurch Airport could be a result of the long period for which this particular airfield has been studied. The assessments for the majority of other airfields were based on occasional short surveys, that would have missed seasonal trends in bird numbers and species diversity.

At Christchurch Airport all of the major hazardous species (except the White-faced Heron) have been reported to be involved in strikes or near misses (see Table 7).

* Table 7: Bird species involved in strikes and near misses at Christchurch Airport (June, 1965 to December, 1969)

Species	Number				
	1965	1966	1967	1968	1969
Gulls	30	19	14	14	22
Magpie	-	-	2	2	2
Hawk	1	1	1	1	3
Pigeon	-	2	-	-	2
Ducks	-	-	1	1	1
Starling and small passerines	-	2	2	4	8
Unknown	3	2	2	1	5

* The information is derived from a summary of reported bird strikes and near misses, provided by the Bird Hazard Committee, Department of Civil Aviation.

The occasional mention of unknown birds could either be from one of the hazardous species or potentially hazardous ones.

Stonehouse (1964) regarded gulls as the birds most dangerous to aircraft on Christchurch Airport. This assessment was made before the introduction of pure jet-engined aircraft on internal flights. Now that these aircraft are in operation, some other birds that were regarded as minor hazards are now considered dangerous. The existing problem, if neglected, may become acute in the near future when the remaining propeller driven planes are replaced by pure jet aircarft.

Birds living in a complex situation such as the airport environment usually adapt themselves to exploit its advantages. Hence the resident bird populations on the airfield get used to the constant disturbance caused either by operational activities or by maintenance needs. They may, however, be momentarily disturbed but soon resume normal activity when the disturbance has passed. The transient populations, on the other hand, use the airfield area occasionally and are not accustomed to the air traffic and associated maintenance activities. They are easily disturbed and put to flight.

Flocks of transient species, on arrival early in the year, are restive while feeding and normally scatter in the air during plane movement. These flocks, however, become less disturbed later in the season. In 1968 when Boeing 737 aircraft were first introduced at Christchurch Airport, Magpies and flocks of Starlings left the feeding grounds for the period the planes were making test flights. These birds now have adapted to the situation and can be seen feeding within a few yards of the runways where jets are operating.

The territorialism in birds such as Magpies has a direct bearing on bird numbers in the area. Territorialism in Magpies helps in maintaining well spaced groups. If these arbitrary divisions are broken down, there is a strong possibility that isolated groups may join and form larger concentrations on the airfield, which will be more dangerous to aircraft than smaller groups.

The danger presented to aircraft by bird flights is dependent upon the distance of the flight from the airfield, the number of birds in the flight, and the height of bird movement. Daily movements of Black-backed Gulls (and also of Pigeons) endanger aircraft using the airfield as they fly in flocks across the airfield and runway approaches at low altitudes en route to feeding areas.

5. AVAILABLE FOOD

5.1 Introduction

The presence of available food is by far the most important factor that can control bird presence on a given area. Studies of bird food resources provide knowledge of: (a) the beneficial effects of birds in either checking untimely outbreaks of insect pests or reducing the numbers of the species that are of economic importance; and, (b) a basis for evaluation of factors that contribute to attracting birds to areas where they are unwanted. From these studies can come an understanding of the relationship between human interests and a bird community, and if necessary, precise control measures can be implemented either to reduce bird numbers or to eliminate the attraction factors.

This section deals with the distribution and abundance of potential food species.

5.2 Available food species

The species list of all potential food items, and also some others that have been mentioned in the text, is outlined below.

5.1A Invertebrate

I. Insects

Order Coleoptera

Family Scarabaeidae

Costelytra zealandica
Aphodius howitti
Pyronota setosa

Family Carabidae

Metaglymma monilifer

Megadromus antarcticus

Hypharpax antarcticus

__________ *abstrusus*

Family Tenebrionidae

Mimopeus sp.

Enneboeus sp.

Family Lathridiidae

Malanophthalma gibbosa

Family Cleridae

Necrobia rufipes

Family Cryptophagidae

Atomaria sp.

Family Coccinellidae

Coccinella undecimpunctata

Family Elateridae

Lacon variabilis

Conoderus exsul

Family Staphylinidae

(species unidentified)

Family Curculionidae

Apion ulicis

Bryocatus sp.

Desiantha maculata

__________ *variabilis*

Hyperodes bonariensis

Irenimus aequalis

Listroderes delaigue

Otiorhynchus ovatus

Order Lepidoptera

Family Pieridae

Pieris rapae

Family Lycaenidae

Zigeria otis

Family Nymphalidae

Pyrameis itea

Family Oecophoridae

Atomotricha sp.

Family Geometridae

Hybernia sp.

Xanthorhoe semisignata

Family Hepialidae

Wiseana cervinata

Family Hypsidae

Nyctemera sp.

Family Pyralidae

Witlesia sabulosella

Family Coleophoridae

Coleophora sp.

Family Crambidae

Crambus cyclopicus

_______ _vittelus_

_______ _schedias_ ?

_______ _scutatus_ ?

Family Noctuidae

Agrotis ypsilon

_______ _admirationis_

Aletia temenaula

_______ _moderata_

Ariatnisa _comma_
Persectania _aversa_
__________ _propria_
__________ _disjungens_

Order Orthoptera

Family Acrididae
Phaulacridium _marginale_

Family Tettigoniidae
Conocephalus (_Xiphidium_) sp.

Family Gryllidae
Nemobius sp.

Family Hemicidae
Pleioplectron _simplex_
Hemiandrus _similis_

Order Dermaptera

Family Forficulidae
Forficula _auricularia_

Order Diptera

Family Therevidae
Anabarrhynchus sp.

Family Syrphidae
Melanostoma _fusciata_

Family Asilidae
Sarapogon sp.

Family Sciomyzidae
Neolimnia _sigma_

Family Mycetophilidae
Platyura sp.

Family Sarcophagidae
Sarcophaga milleri

Family Chironomidae
Chironomus sp.

Family Sciaridae
Sciara sp.

Family Drosophilidae
Drosophila sp.

Family Sphaeroceridae
(species unidentified)

Family Dolichopodidae
(species unidentified)

Family Calliphoridae
(species unidentified)

Order Hemiptera

Family Pentatomidae
Dictyotus caenosus
Rhopalomorpha lineolaris

Family Lygaeidae
Nysius sp.
______ *huttoni*
Regatarma forsteri
(one unidentified species)

Family Reduviidae
Oncocephalus sp. ?

Family Cynidae

Choerocydnus nigrosignatus

Family Cicadidae

Melampsalta sp.

Order Hymenoptera

Family Psammocharidae

Salius sp.

Family Braconidae

Adelius sp. ?

(one unidentified species)

Family Formicidae

Chelaner sp. ?

Family Ichneumonidae

(species unidentified)

Order Odonata

Family Coenagriidae

Xanthocnemis zealandica

Order Psocoptera

(unidentified)

Order Collembola

Family Hypogastruridae

Hypogastrura sp.

II. Earthworms

Order Terricolae

Family Lumbricidae

<u>Lumbricus</u> sp.

<u>Allolobophora</u> sp.

III. Arachnids

Order Araneida

Family Araneidae

<u>Araneus</u> sp.

_______ <u>pustulosus</u>

Family Dipluridae

<u>Aparua</u> sp.

Family Erigonidae

<u>Aulacocyba</u> <u>subitanea</u>

<u>Araerucus</u> <u>humilis</u>

Family Linyphiidae

<u>Leptyphantes</u> <u>tenuis</u>

<u>Meioneta</u> sp. ?

Family Theridiidae

<u>Lithyphantes</u> sp.

Family Lycosidae

(more than one species)

Family Salticidae

(species unidentified)

Family Gnaphosidae

(species unidentified)

Order Opiliones

Family Phalangiidae
Phalangium opilio

IV. Woodlice

Order Isopoda

Family Oniscidae
Porcellio scaber

V. Snails

Order Pulmonata

Family Endodontidae
Laoma sp.

5.2B Vertebrate

I. Lizards

Order Squamata

Family Scincidae
Leiolopisma sp.

5.2C Plant material

I. Seeds

Family Gramineae

Lolium sp.
Vulpia sp.
Poa sp.
Anthoxanthum odoratum
Stipa sp. ?
Triticum sp.
Avena sp.

Family Compositae

Achillea sp.
Crepis capillaris
Helminthia sp.
Taraxacum officinale

Family Papilionaceae

Trifolium sp.
Cytisus scoparius
Ulex euroaeus
Pisum sp.

Family Caryophyllaceae

Stellaria media

Family Geraniaceae

Erodium sp.

Family Oxalidaceae

Oxalis sp.

Family Chenopodiaceae

Chenopodium album

Family Polygonaceae

Polygonum sp.

Family Rosaceae
Rubus sp.

Family Solanaceae
Solanum sp.

Family Caprifoliaceae
Sambucus sp.

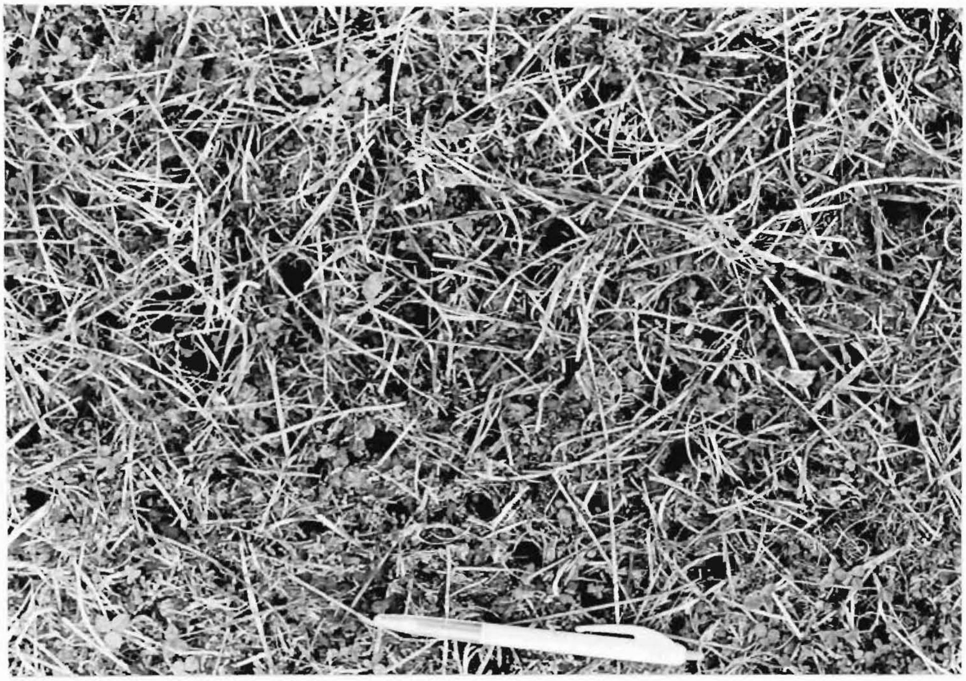
5.3 Distribution and abundance of food species

5.3A Introduction

Christchurch Airport has a permanent pasture which is undisturbed, except for mowing two or three times a year, and provides an excellent, stable habitat for pasture invertebrates. On cultivated areas in general, due to constant tilling and subsequent exposure, losses in number of soil animals have been reported by Zicsi (1967) and a gradual decrease in the biological activity was observed by Bosse (1967).

The estimates of relative abundance of insects, earthworms and arachnids presented here, are based on the concept of "available abundance" to birds. Animals living on and above the ground surface can be more easily preyed upon than the subterranean forms. Some birds, especially Starlings (*Sturnus vulgaris*), are, however, capable of preying on the latter. Measurements of 150 Starling probes (see Plates 11, 12) at three feeding places during the wet season indicated that these birds can effectively probe down to 0.8".

Soil analysis, on the three feeding sites examined for probe depth, yielded many soil forms in the 0.0 - 0.8" zone. Before reaching any general conclusions, it is pertinent to consider the effects of such ecological factors as precipitation and drying conditions, as under the influence of such



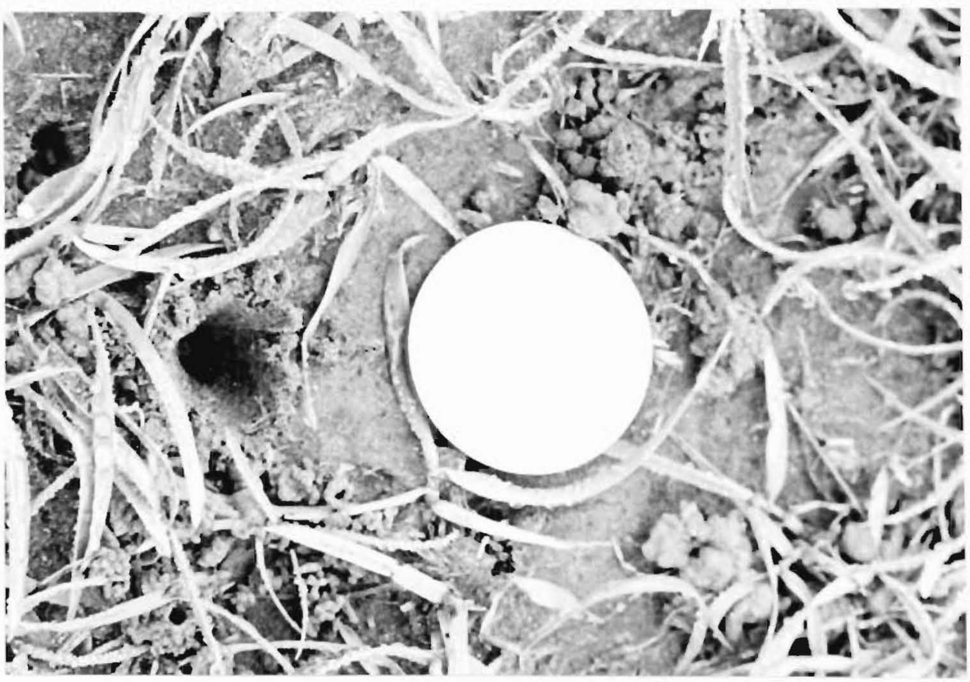


Plate 11

An area of the airfield pasture showing the density of probes made by Starlings (*Sturnus vulgaris*). Note the regular spacing of the probes.

Plate 12

A typical probe hole made by a Starling, its relative size shown by the 20 cent coin alongside.

factors many subterranean forms readily change their depth distribution. The species that are living at, say, 1" depth may either move upward due to rainfall or move further down under drying conditions, thereby effectively controlling their availability/non-availability to predators. Considerations such as these made it imperative that the assessment of invertebrate food take into account their available and/or possible available abundance in the field.

5.3B Insects

I. Introduction

Insects are by far the most important group of invertebrates found in the diet of most pasture-feeding carnivorous or omnivorous birds. Additionally some grain-eating birds such as the House Sparrow (Passer domesticus) are fed an exclusively insect diet as nestlings (Southern, 1945).

Ten orders of insects are present at Christchurch Airport; Coleoptera (beetles and weevils), Lepidoptera (butterflies and moths), Diptera (flies), Hemiptera (mostly plant bugs), Orthoptera (grasshoppers and crickets), Dermaptera (earwigs), Odonata (damsel- and dragonflies), Hymenoptera (bees and wasps), Psocoptera (book-lice) and Collembola (spring-tails). Of these orders, only the first six are of major significance as bird food.

Depending on the stage of their life history, these insects are either free-flying, live amongst vegetation, are surface dwellers, found in the litter zone, or are true soil inhabitants.

Seasonal distribution and relative abundance of major insect orders, in relation to their significance as bird food, is discussed below.

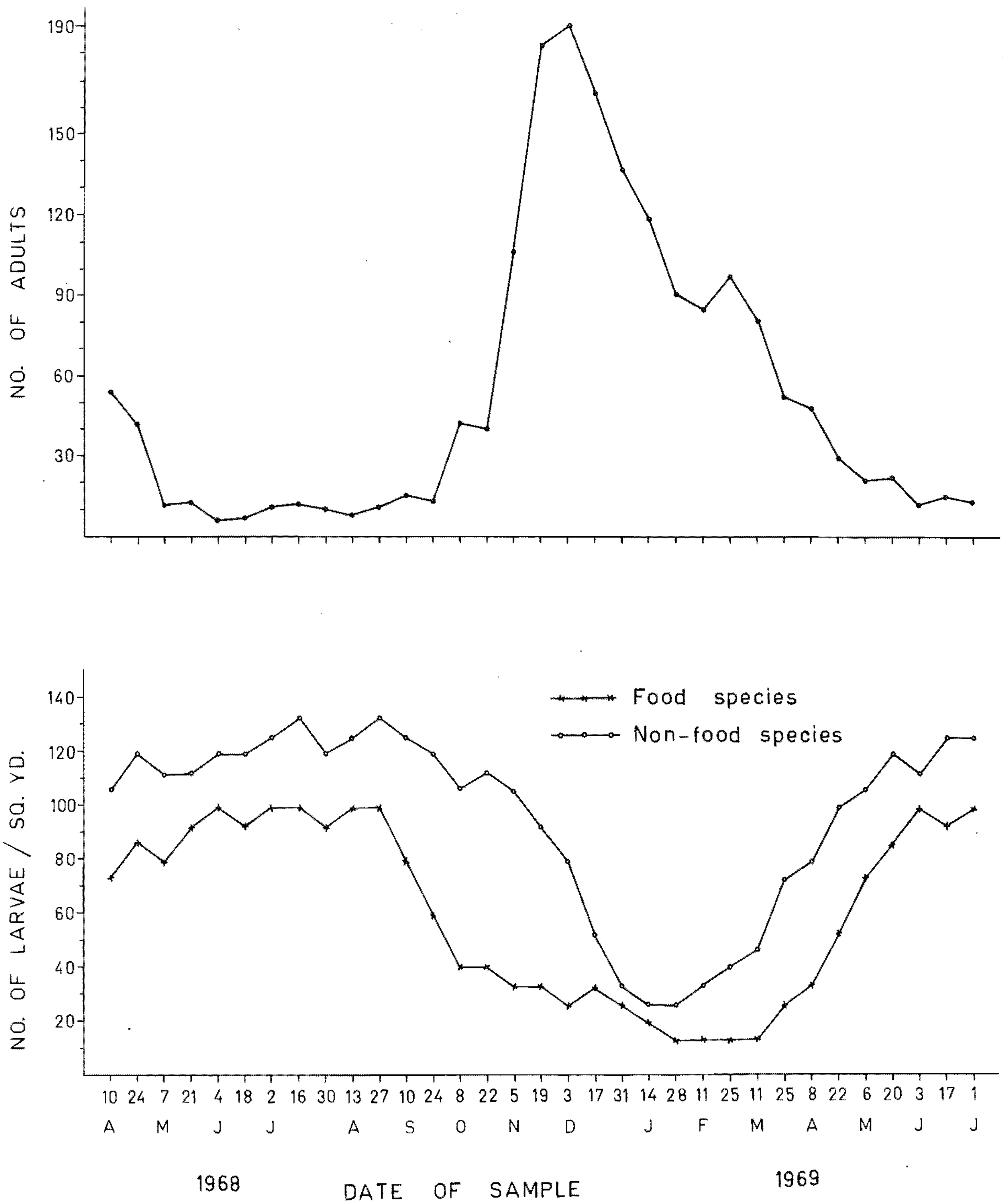
II. Coleoptera

The numbers of pit-trapped beetles and weevils caught (at weekly intervals) from April, 1968 to July, 1969 are shown in the upper half of Figure 13. They represent the totals obtained from the ten pit traps set in each of the four experimental plots.

The overall trend is low abundance during the winter and high in the summer. During the last week in October Costelytra zealandica, the Grass-grub Beetle, began to dominate the samples and reached a peak during the latter half of November and early December before declining and eventually disappearing in early January. Adults of Aphodius howitti, the Tasmanian Grass-grub Beetle, and Pyronota setosa became dominant in January and February and occurred until late March. The following species were frequent only during October through to April and were in much smaller numbers: Metaglymma monilifer, Megadromus antarcticus, Mimopeus sp., Hypharpax antarcticus, H. abstrusus, Enneboeus sp., Necrobia rufipes, Coccinella undecimpunctata, Malenophthalma gibbosa, Atomaria sp. and members of the family Elateridae.

Weevils, especially Desiantha maculata, D. variabilis, Irenimus aequalis, Otiorhynchus ovatus and Hyperodes bonariensis, were present commonly from January to May when their numbers decreased considerably. Listoderus delaigue, Apion ulicis and Bryocatus sp., were rare.

The numbers of beetle and weevil larvae shown in the lower half of Figure 13, were obtained from fortnightly soil samples and are the totals of ten samples taken from each of the four experimental plots. These have been grouped into "food species", i.e. definitely eaten by birds, and "non-food species". The latter category includes immature "food species", which were too small as yet to contribute significantly as food, as well as species which were naturally small and uncommon. Numbers of larvae remained fairly constant during winter but dropped gradually from October to a low in January and February. This decline may have been caused by



NO. OF ADULTS
190
150
120
90
60
30
NO. OF LARVAE / SQ. YD.
140
120
100
80
60
40
20
Food species
Non-food species
10 24 7 21 4 18 2 16 30 13 27 10 24 8 22 5 19 3 17 31 14 28 11 25 11 25 8 22 6 20 3 17 1
A M J J A S O N D J F M A M J J
1968
DATE OF SAMPLE
1969

Figure 13

Seasonal variation in numbers of beetles and weevils (Coleoptera) on the airfield pasture. Adults are shown in the upper graph, larvae in the lower.

the onset of pupation followed by emergence for there is a broad relationship between the reduction of larvae and the increase of adults. Thereafter, from February through to June and July, the numbers of larval beetles and weevils showed a steady increase.

To sum up, the numbers of adult beetles and weevils caught in the pit traps were low (about 5 per week) during the winter months (May to September) but high (about 40 to 100 per week) during the summer months (October to April). The increase is roughly in order of magnitude but it is not quantitative; the adults move actively and there is no way of assessing how far they roamed before tumbling into the pit traps (also see Section 5.3E.II). They may have even come from outside the experimental plots. Moreover, these were weekly samples, necessitated by the possibility of captured carnivorous forms eating other species if left too long in the traps. The results presented in the upper half of Figure 13, correspond with the dates of fortnightly soil samples and are the sum of two weekly collections of beetles and weevils in the pit traps.

The numbers of larval beetles and weevils show a broad inverse relationship to those of the adults. During the winter months (May to August) the density of "food and non-food" species was about 100 per square yard. It declined during the spring to reach a minimum of about 15 to 30 larvae per square yard in the summer (late December to February) before rising, in the autumn, to reach about 100 per square yard in the winter.

III. Lepidoptera

Three butterfly and twenty moth species were identified from the airfield pasture. The butterflies _Pieris rapae_, _Pyrameis itea_ and _Zigeria otis_ were seen only during the flowering season. The first two can only be regarded as visitors on the airfield pasture while the third was commonly recorded in sweep samples during summer.

The distribution and abundance of adult moths, Crambus sp., Witlesia sabulosella and Xanthorhoe semisignata for the period December (1968) to May (1969) is presented in Table 8. During the daytime these moths remained quietly in the vegetation unless disturbed and were readily flushed out by means of the sweep net. In the table the average number of moths for each fortnightly sample is a mean of twenty sub-samples of a yard square each and indicates that the adults of these species were most abundant from January to early March. The numbers were lower before and after this period.

Moths of Aletia sp., Persectania sp., Agrotis sp. and Ariatnisa comma were regularly collected in a light trap from October (1968) to January (1969) after which their occurrence became irregular while Wiseana cervinata appeared only from October to November (1968). Adults of Coleophora sp. were common from November (1968) to January (1969). This moth is small (total length 0.25") and is of insignificant food value; none was found in any of the bird stomach samples. The Atomotricha sp. was uncommon and only the brachypterous females were sometimes recorded in soil samples during April and May.

Lepidopteran larvae whenever available to insectivorous birds tend to form a major portion of their diet. Distribution and abundance of some of the major surface living and subterranean species on the airfield pasture is described below.

Porina (Wiseana cervinata) caterpillars were recorded in the soil cores from late December (1968) to late April (1969) and reached a peak of about 40 to 50 per square yard during February (see Table 9). These caterpillars are generally found within an inch from the surface during the early stages of development. Later on they live in burrows and are found at a greater depth (6 to 10") during the day, emerging only at

Table 8: Number of <u>Crambus</u> sp., <u>W</u>. <u>sabulosella</u> and <u>X</u>. <u>semisignata</u> moths per square yard of net sweep

	1968		1969									
Date of sample	4/12	18/12	1/1	15/1	29/1	12/2	26/2	12/3	26/3	9/4	23/4	7/5
No. of moths	2.1	4.5	6.3	6.4	6.2	6.1	5.5	5.0	3.1	2.3	1.7	0.6

Table 9: Number of <u>W</u>. <u>cervinata</u> caterpillars per square yard of top soil (down to 3.5")

	1968		1969								
Date of sample	17/12	31/12	14/1	28/1	11/2	25/2	11/3	25/3	8/4	22/4	6/5
No. of caterpillars	0.0	13.2	33.0	46.3	52.9	46.3	39.7	33.0	19.8	6.6	0.0

Table 10: Relative number of <u>Aletia</u> sp., <u>Agrotis</u> sp. and <u>Crambus</u> sp. caterpillars per square yard of net sweep

	1968														
Date of sample	24/4	7/5	21/5	4/6	18/6	2/7	16/7	30/7	13/8	27/8	10/9	24/9	8/10	22/10	5/11
No. of caterpillars	0.0	3.2	7.4	11.8	14.2	13.7	12.9	11.7	10.5	11.1	9.2	8.1	7.6	3.2	1.6

night to feed (Cottier, 1956). The numbers showed a decrease in late March and they were absent from the top soil at the end of April.

Caterpillars of Aletia sp., Agrotis sp., and Crambus sp. were common in the pasture vegetation from May to October during 1968. Their relative abundance and distribution obtained from sweep samples is given in Table 10. The figures represent the means derived from twenty sub-samples of one square yard each. The caterpillars were most abundant during June and July.

These caterpillars in the early stages of their life cycle were present among the vegetation and appeared regularly in sweep samples. During the later stages of development, however, they drop down onto the soil surface and at that stage most of them would have escaped from the sweep net. For this reason, and also due to the inefficiency of the sweep net to collect total number of caterpillars within the area covered, their abundance is presented with some reservation. During the period when these caterpillars were collected individuals of Aletia moderata were common from September to early October while A. temenaula were infrequent. Caterpillars of Crambus sp. were collected mostly during June to early September. The Agrotis sp. were less abundant than either Aletia sp. or Crambus sp.

IV. Orthoptera

The order Orthoptera was represented by two species of wetas (Hemiandrus similis and Pleioplectron simplex), a single species of both short-horned (Phaulacridium marginale) and long-horned grasshoppers (Conocephalus (Xiphidium) sp.) and a single cricket (Nemobius sp.).

The distribution and abundance of wetas is unknown as the two species occurred infrequently in pit trap samples over a period ranging from August (1968) to February (1969). The

Table 11: Seasonal distribution of *P. marginale* per square yard

	1968		1969									
Date of sample	17/12	31/12	14/1	28/1	11/2	25/2	11/3	25/3	8/4	22/4	6/5	20/5
No. of grasshoppers	1.0	1.5	1.9	2.1	2.2	2.4	2.3	1.9	1.6	0.8	0.3	0.0

Table 12: Seasonal distribution of *Nemobius* sp. per square yard

	1969												
Date of sample	14/1	28/1	11/2	25/2	11/3	25/3	8/4	22/4	6/5	20/5	3/6	17/6	1/7
No. of crickets	1.6	2.9	3.2	3.5	3.6	3.4	3.6	3.5	3.1	2.3	1.5	0.5	0.0

seasonal distributions of grasshoppers and crickets based on direct counts within a square yard quadrat are presented below. These values are means derived from twenty sub-samples, each of one square yard.

IV.a. Grasshoppers

The nymphs of P. marginale first appeared in late October (1968) on the sticky traps. At that stage these insects were too small for direct counts and they could avoid the sweep net either by jumping away or crawling towards the surface. By late December they reached an appreciable size and being brachypterous could be counted within a quadrat. Their seasonal distribution is presented in Table 11.

During the active period these insects are very agile and perhaps it is for this reason that they escape active predation by birds. Towards the end of the season (around April) they become lethargic and form an easy prey for birds.

Conocephalus (Xiphidium) sp. was only recorded (during summer) along the open water channels (see Plate 13) in the north and south of the main runway and was absent from other areas of the airfield pasture.

IV.b. Crickets

The activity of Nemobius sp. started slightly later than that of the grasshoppers. The first nymphs on sticky traps were recorded during the later half of November. Their seasonal distribution was determined in the same way as for grasshoppers and the results are presented in Table 12.

The activity period lasted longer than P. marginale and decreased with the start of severe winter conditions. In comparison to P. marginale, Nemobius sp. is less active, but can escape capture by hiding amongst thick grass cover. It is suggested that in such situations, despite their quick movement on the surface, they could be picked up by common

Plate 13

A view of the open water channels that run across the airfield north and south of the main runway.

pasture-feeding birds such as the Magpie (*Gymnorhina hypoleuca*) and the Starling (*Sturnus vulgaris*).

V. Dermaptera

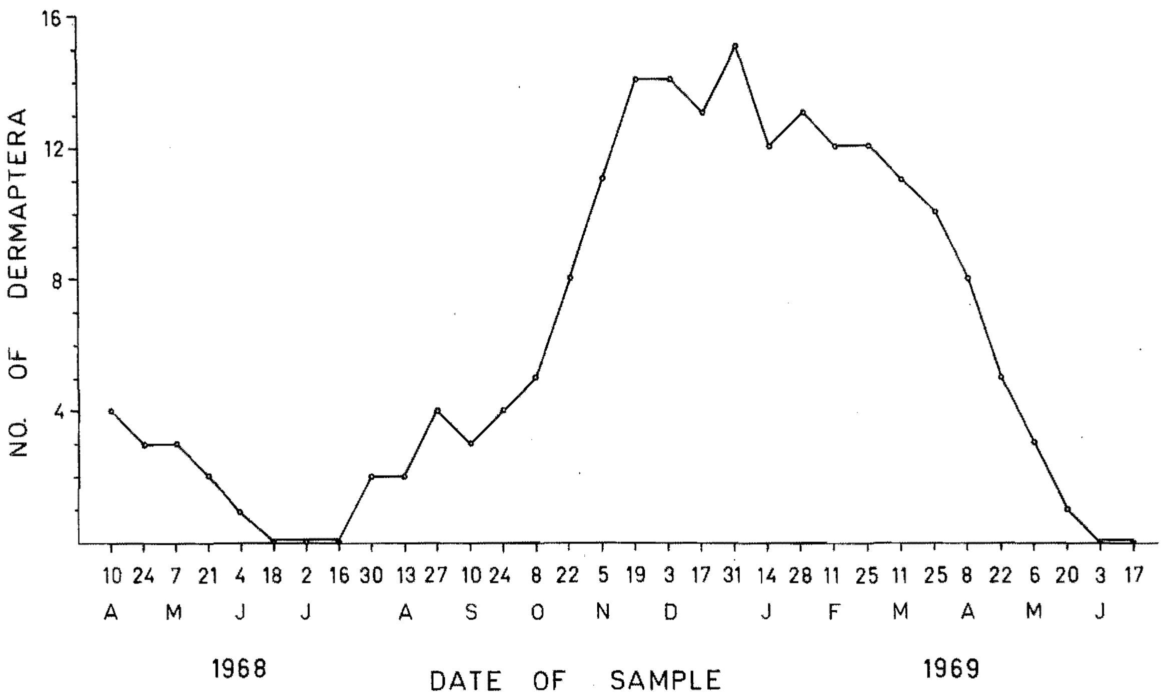
The order Dermaptera was represented by a single species *Forficula auricularia*, which is widely distributed on the pasture. It is a subterranean form that emerges only at night. An estimate of its activity was obtained through individuals collected in pit traps (see Figure 14). This data suggests that they were active from the end of July (1968) to May (1969), reaching maximum activity over the summer months. *F. auricularia* has been reported (Cottier, 1956) to hibernate, which accounts for its decreased numbers and eventual absence in pit traps during colder months.

VI. Diptera

Thirteen species of flies were recorded from the airfield pasture. Amongst these, four species *Drosophila* sp., *Sciara* sp. and one unidentified species of each of the families Sciaridae and Sphaeroceridae were too small (under 0.187") to be of any significance.

Adults of most species were collected either by sweeping the pasture or light trapping. Members of the family Dolichopodidae (unidentified) were common during November and December (1968). *Neolimnia sigma* and *Melanostoma fusciata*, during January to March, were collected only along the two water channels, north and south of the main runway. Adults of *Chironomus* sp. were regularly collected in the light trap during November and December while the morphologically similar *Platyura* sp. was recorded only in October (1968).

The largest and most abundant species *Sarcophaga milleri*, *Anabarrhynchus* sp. and *Sarapogon* sp., were present mostly on warm, still days during January to March. Predation by birds seems likely under windy conditions when these flies were seen



16
12
8
4
NO. OF DERMAPTERA
10 24 7 21 4 18 2 16 30 13 27 10 24 8 22 5 19 3 17 31 14 28 11 25 11 25 8 22 6 20 3 17
A M J J A S O N D J F M A M J
1968
DATE OF SAMPLE
1969

Figure 14

Seasonal variation in numbers of earwigs (*Forficula auricularia*), Dermaptera, on the airfield pasture.

resting among vegetation. Because of their dispersal power, uneven distribution and changes in activity due to varying weather conditions, an estimate of their seasonal abundance was not possible.

Larvae of Chironomus sp., Sarapogan sp. and Anabarrhynchus sp. were regularly recorded in soil samples; numbers of these per square yard were estimated to range from 26 in June to 60 in January and February. Maggots belonging to the family Calliphoridae were observed on sheep carcasses during January only.

VII. Hemiptera

Nine hemipteran species were present during summer. These were Nysius huttoni, Nysius sp., Rhopalomorpha lineolaris, Choerocydnus nigrosignatus, Dictyotus caenosus, Regatarma forsteri, Oncocephalus sp. (?), Melampsalta sp. and an unidentified species of the family Lygaeidae.

N. huttoni was the most common pasture form during October (1968) to April (1969), being abundant during January to March. During this period they were commonly present in pit traps and were regularly seen on bare patches of pasture. As these insects are capable of flying, their presence in pit trap samples was erratic and numbers were inconsistent. Because of their size (just over 0.125") and camouflaged colouration it was impossible to estimate numbers on the pasture by direct count and as most live close to the ground they could not be adequately sampled by net sweeping. Nymphs and adults of other species (except C. nigrosignatus which was observed along with N. huttoni, and Melampsalta sp. which was rare) were present only among the luxuriant plant growth along the two water channels. They were common on such areas during December (1968) to early March (1969). In January and February these species were appearing in sweep samples at an average of ten individuals per square yard of sweep. Dominant amongst them were _Nysius_ sp. and _R. lineolaris_.

5.3C Other orders

Insects belonging to the orders Hymenoptera, Odonata, Collembola and Psocoptera were also recorded on the airfield pasture. Their importance as bird food is negligible either due to their smallness, or scarcity, and/or mode of life. Only a few hymenopteran insects belonging to families Braconidae, Ichneumonidae, Formicidae and Psammocharidae were collected from the pasture and these were negligible in bird gut samples. Some adults of the damsel fly (_Xanthocnemis zealandica_) were collected during February and March from the areas along the water channels, but never recorded in bird gut samples. Members of Collembola (_Hypogastrura_ sp.) and Psocoptera are too small (under 0.062") to be of any importance as food of major bird species.

A snail (_Laoma_ sp.) and a woodlouse (_Porcellio scaber_) were common along the water channels and under the stones respectively. _P. scaber_ appeared in a few Magpie (_G. hypoleuca_) gut samples and _Laoma_ sp. appeared in a few Starling (_S. vulgaris_) gut samples.

5.3D Earthworms (Lumbricidae)

I. Seasonal distribution

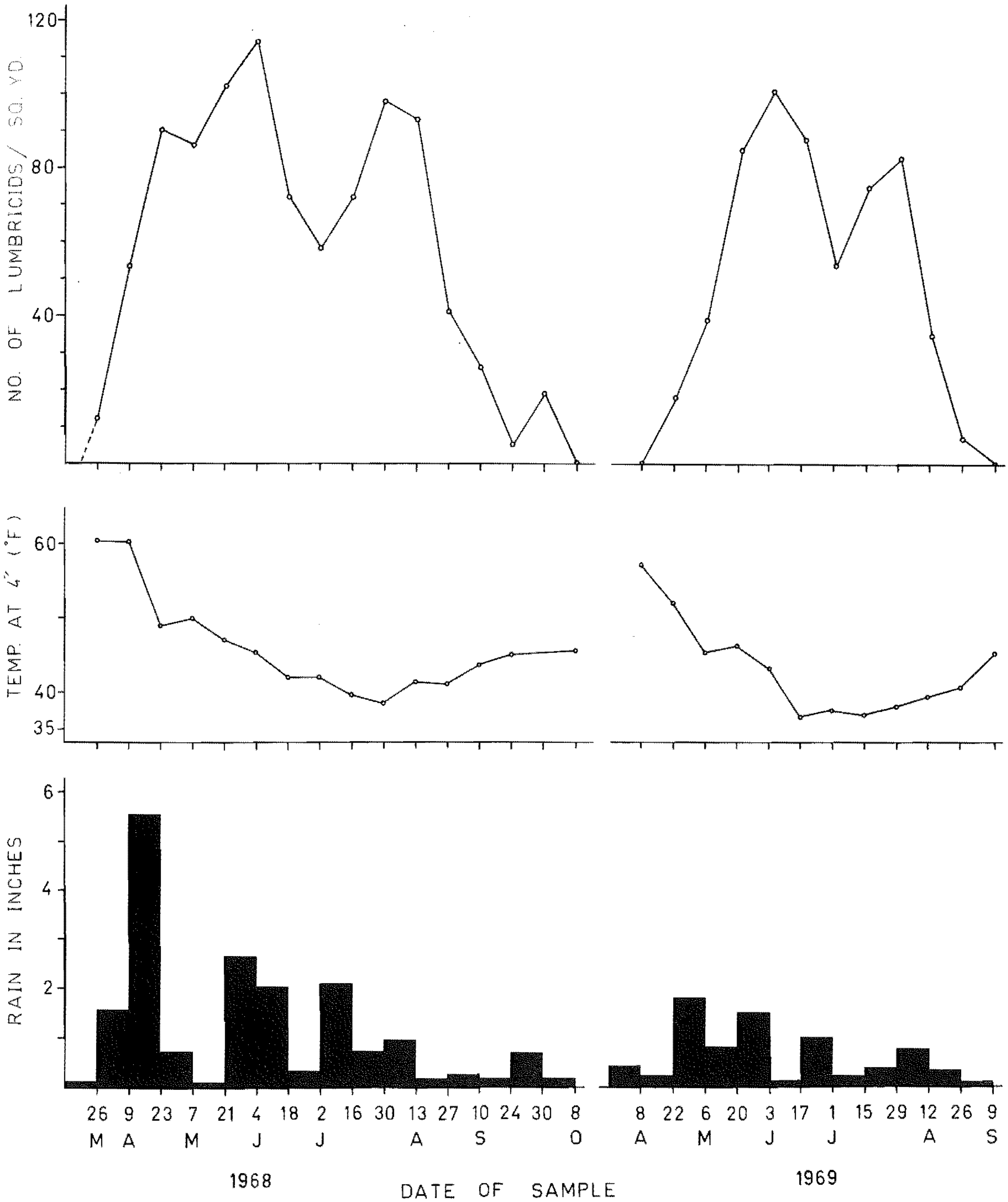
Seasonal fluctuations in earthworm (Lumbricidae) numbers are determined by a host of abiotic and biotic environmental factors, amongst which rainfall and temperature appear critical. In moist and mild conditions, earthworms are normally found close to the surface while in dry periods they retreat into deep burrows. Temperature and moisture are regarded by many workers (Evans and Guild, 1947; Gerard, 1967; Reineck and Ljungström, 1969) as primary factors for earthworm population fluctuations.

The merits and demerits of various methods of earthworm sampling have been discussed by Svendsen (1955) and Satchell (1969) and include the use of permanganate (for earthworm extraction) and digging and hand-sorting. Permanganate treatment of the airfield pasture prior to digging helped in readily obtaining those individuals that were near the surface. But a comparison of the numbers of worms collected by permanganate treatment and those obtained by subsequent digging indicated that only about one third of the earthworms came out on the surface after permanganate treatment, as opposed to two thirds obtained by digging. All the results presented here were obtained primarily by digging.

Seasonal abundance of earthworms in the top 3.5" of soil during 1968 and 1969 is shown in Figure 15. Peak abundance in 1968 ranged from late March to early October while in 1969 it was from April to early September. The data on soil temperature and rainfall, shown in the figure, is based on means of the fortnightly conditions preceding the date of sampling.

The intrusion of earthworms into the top soil began just after the autumn rainfall in March (1968) and April (1969) and in both years a peak was reached during May and June when a maximum of 114 and 101 earthworms per square yard were recorded for respective years. The numbers were lower during frosty conditions in late June and early July, but increased to a second peak during late July and early August. By this time, due to lack of sufficient moisture and drier conditions, the earthworms moved downward and eventually disappeared from the top soil in September-October, an activity evidently dependent upon seasonal conditions. In 1968 by the 24th September the numbers had reached seven per square yard and a wet spell increased this to nineteen on the 30th. An extra sample was obtained on that date to determine the effect of rainfall.

The pattern of activity was the same for 1969 except that



NO. OF LUMBRICIDS/ SQ. YD.
120
80
40
TEMP. AT 4" (°F)
60
40
35
RAIN IN INCHES
6
4
2
26 9 23 7 21 4 18 2 16 30 13 27 10 24 30 8
M A M J J A S O
8 22 6 20 3 17 1 15 29 12 26 9
A M J J A S
1968
1969
DATE OF SAMPLE

Figure 15

Seasonal abundance of earthworms (Lumbricidae) in the top 3.5" of soil in relation to rainfall and temperature data.

it was shorter than the preceding year, perhaps because of less rainfall.

During summer, earthworms were recorded at a depth of 8" and below in the sub-surface alluvial soil. At that time they were found to be coiled and occasionally knotted in isolated pockets.

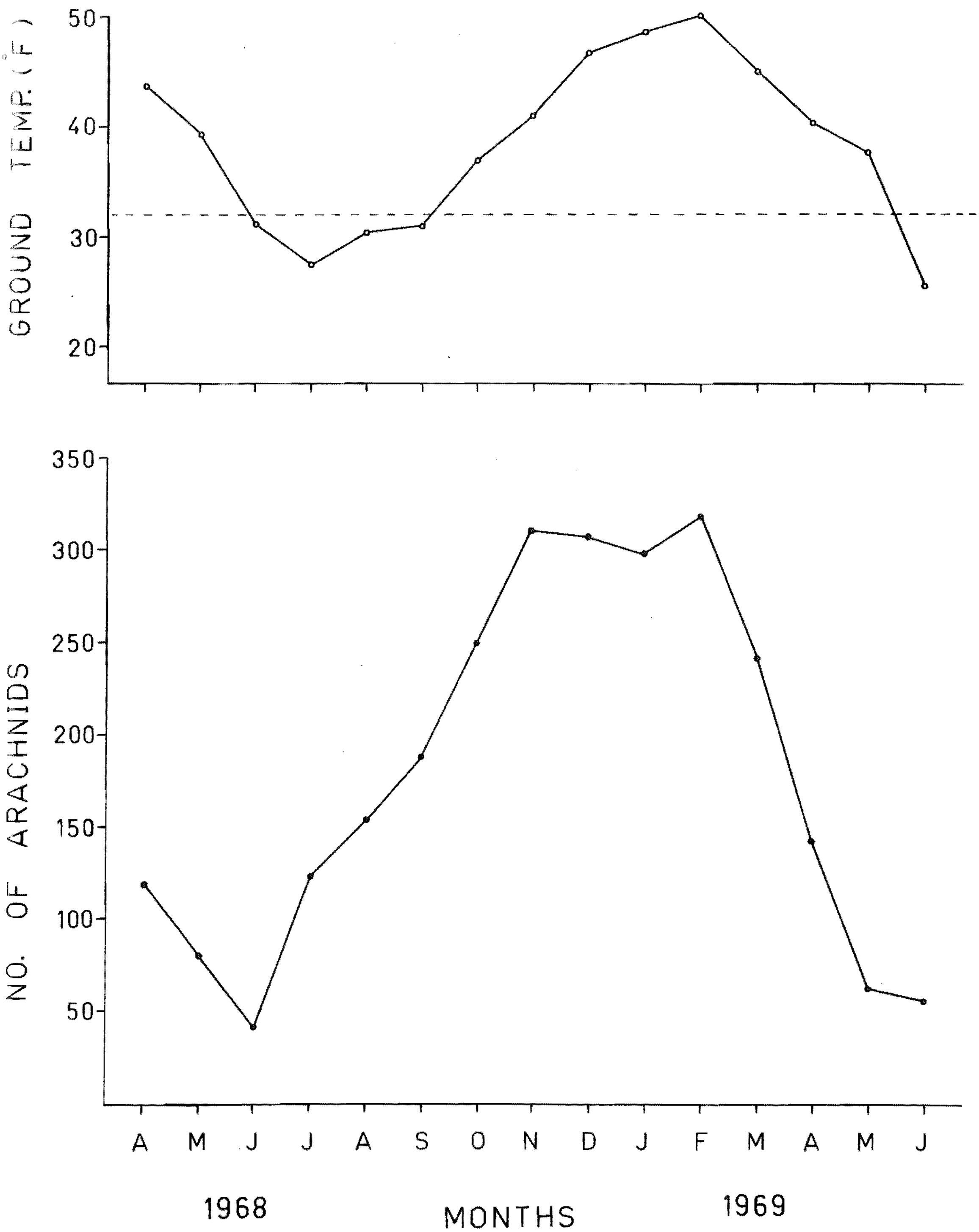
5.3E Arachnids

The orders Araneida (spiders) and Opiliones (harvestmen) of the class Arachnida were represented by at least eleven and one species respectively. These, in comparison to insects and earthworms, are of minor importance as a source of bird food, and are collectively referred to here as arachnids.

I. Seasonal activity

The arachnid seasonal activity was determined by pitfall trapping. During the period April (1968) to June (1969) weekly samples were obtained from forty pit traps, equally distributed on four experimental plots. The seasonal trend in numbers is shown in Figure 16, which also indicates monthly mean temperature on the grass at 0900 hours. Maximum numbers were obtained during late spring to early autumn. Numbers were higher during October and March, reaching a peak in the summer months of November to February, while lower counts were obtained during April to September.

This trend in activity corresponds with the ground temperature on the airfield pasture and exhibits a correlation (Kendall's rank order correlation test, $P < 0.005$) between increased activity and higher temperatures and vice versa. It is suggested that temperature (besides other factors) plays a major role in the activity of the arachnid population on the airfield pasture. It can, however, be argued that despite colder temperatures in August and September (1968) the numbers recorded were greater than in May of the same year



GROUND TEMP. (°F)
50
40
30
20
NO. OF ARACHNIDS
350
300
250
200
150
100
50
A M J J A S O N D J F M A M J
1968
MONTHS
1969

Figure 16

Seasonal variation of the number of arachnids caught in pit traps showing correlation with ground temperature. On the temperature graph, broken line indicates freezing point.

when the temperature was higher. This is perhaps due to a reduction in the adult population just after the breeding season.

Spiders have been reported to breed during September to March (Forster, 1967) while harvestmen eggs are laid during October to December (Forster, 1954). In temperate climates spider numbers and activity are greatly reduced with the onset of winter. This effect is less marked in the New Zealand fauna, probably due to milder winters (Forster, 1967). On the airfield pasture the activity and possibly also the numbers of arachnids decreased with the start of the cold rainy period in April (1968).

II. Discussion

The efficiency of pit traps for estimating populations of surface-dwelling invertebrates has been questioned by many workers (Grüm, 1959; Briggs, 1961; Mitchell, 1963; Greenslade, 1964; Southwood, 1966).

The pit traps used in the present study were passive devices, which roaming arachnids fell into, so the numbers caught can be considered as an index of arachnid activity. In other words, fewer arachnids were active in the cold winter months than in the warm summer months. It can not be decided from the data available, whether the low winter numbers were due to decreased arachnid activity, or a drop in the population. Nor can we decide if the high summer numbers are due to increased arachnid activity, or an increased population. What is evident, however, is that more arachnids were trapped in summer than in winter and that there is more opportunity for birds to prey on arachnids during summer than in winter.

5.3F Seeds

The airfield and the surrounding floral habitat can be divided into cultivated and non-cultivated areas. Cultivated habitats include areas used for agricultural purposes (these mostly surround the airport's operational boundary) while non-cultivated habitats include the major portion of the area within the operational boundary and part of the surrounding fields. Both these areas harbour many flowering plants and the seeds of these are taken by birds as part of their diet.

Cultivated areas include fields used for the cultivation of wheat (Triticum sp.), oats (Avena sp.), peas (Pisum sp.) and clover (Trifolium sp.). These fields were harvested from December to January, during which period Pigeon (C. livia) flocks appeared on these fields. The non-cultivated pasture contains many flowering plants such as vetches (Vicia sp.), broom (Cytisus scoparius), gorse (Ulex euroaeus), clover (Trifolium sp.), dandelion (Taraxacum officinale), ryegrass (Lolium sp.), hairgrass (Vulpia sp.), sweet vernel (Stellaria media), storkbill (Erodium sp.), Oxalis sp. and Poa sp. Seeds of these plants when mature become available to smaller birds such as Goldfinch (Carduelis carduelis), Greenfinch (Chloris chloris), Sparrow (Passer domesticus), Yellowhammer (Emberiza citrinella), Skylark (Alauda arvensis) and Pipit (Anthus novaeseelandiae) while seeds of berry producing plants, such as Rubus sp., were occasionally taken by the Starling (Sturnus vulgaris).

The amount of seed available to birds on the uncultivated pasture within the airfield's operational boundary is believed to be dependent on the time of mowing. If it is carried out during the early stages of flowering, the production of mature seeds is greatly reduced.

Table 13: Number and species of birds examined during March 1968 to March 1969

Species	Months													Total of
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	each species
Larus dominicanus	3	5	3	2	5	2	-	-	-	-	-	-	-	20
Larus bulleri	7	2	2	2	1	3	9	-	-	-	-	-	-	26
Gymnorhina hypoleuca	6	4	4	7	4	4	5	3	4	6	7	6	10	70
Sturnus vulgaris	7	8	12	11	8	9	9	32	17	12	15	15	4	159
Columba livia	-	8	-	-	-	4	-	-	-	6	-	-	-	18
Passer domesticus	4	-	-	-	-	-	-	-	-	3	4	4	-	15
Carduelis carduelis	-	-	-	-	-	-	-	-	-	1	3	2	-	6
Chloris chloris	-	-	-	-	-	-	1	-	-	3	-	2	-	6
Alauda arvensis	-	-	-	-	-	1	-	1	4	1	2	-	-	9
Anthus novaeseelandiae	-	-	-	-	1	1	-	1	2	-	-	-	-	5
Total for month	27	27	21	22	20	22	25	37	27	32	31	29	14	

6. BIRD FOOD AND FEEDING HABITS

6.1 Introduction

In designing methods of bird control for an area, a knowledge of bird food resources becomes essential. Once these resources are evaluated and related to bird diet, bird control may be possible by denying them their food supply.

Methods of avian food assessment are varied and the selection of the most appropriate method largely depends on the purpose for which the information is required. This aspect has been reviewed by Hartley (1948) and Gibb and Hartley (1957). In the present study quantitative assessments were made so as to gain information on the seasonal importance of certain invertebrate groups as bird food.

It cannot be over-emphasized that the mere presence of a bird on a given area is no indication that food is available. Actual food taken can be determined by direct observations of feeding or by examination of stomach contents and faecal pellets (for other methods see Gibb and Hartley, 1957). The information provided here is mainly based on the analysis of gizzard/crop contents and partly on field observations.

6.2 Species examined

The number and species of birds examined during the course of food assessment investigation (March 1968 to March 1969) for each month is given in Table 13.

Identification of food species in small passerines such as the House Sparrow (*Passer domesticus*), Goldfinches (*Carduelis carduelis*) and Greenfinches (*Chloris chloris*) and the Pigeon (*Columba livia*) was facilitated by the presence in these species of a crop. But in gulls (*Larus dominicanus* and *L. bulleri*), Magpies (*Gymnorhyna hypoleuca*), Starlings (*Sturnus vulgaris*), Skylarks (*Alauda arvensis*) and the New Zealand Pipit

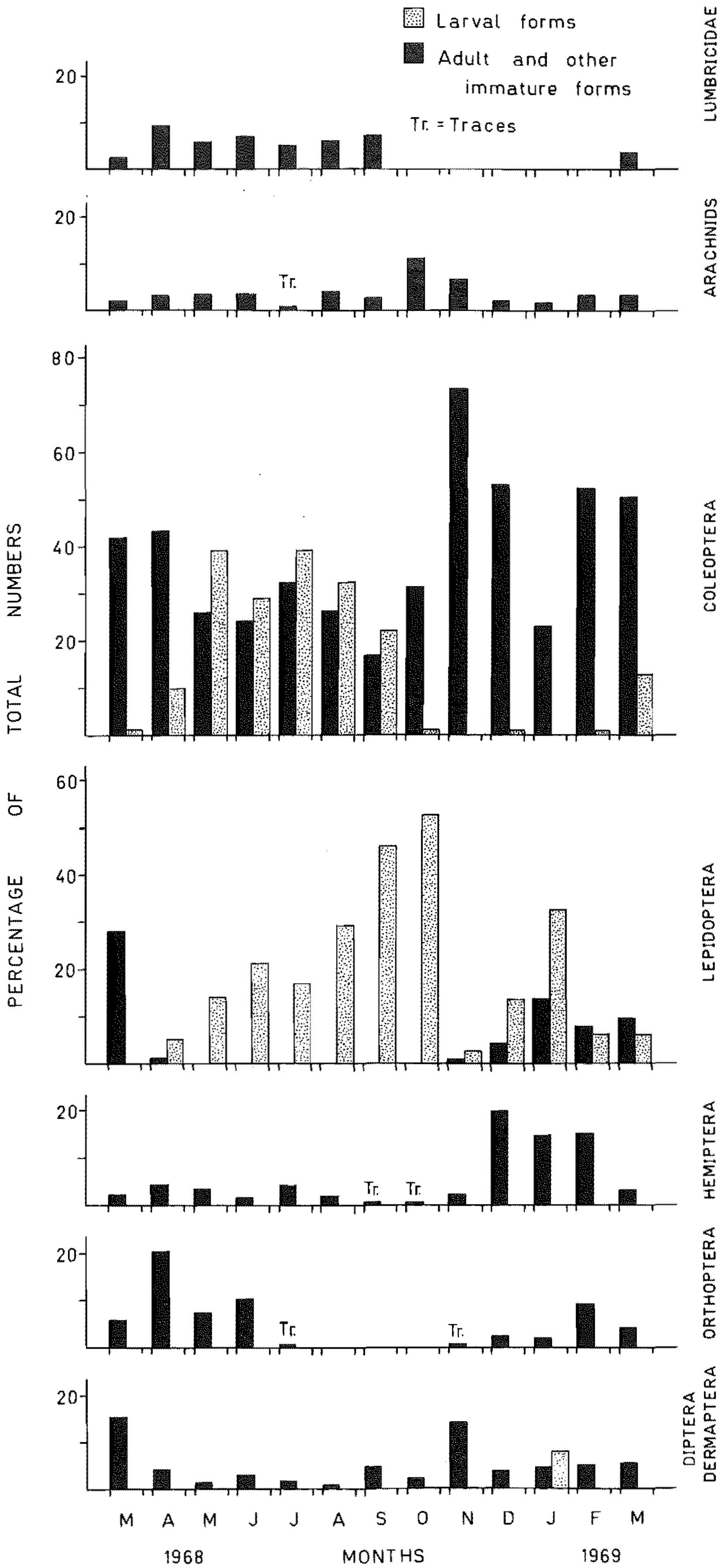
(Anthus novaeseelandiae), due to the lack of a crop, the food is directly taken into the gizzard and is quickly mutilated, rendering recognition difficult.

The adult, larval and nymphal stages of insects were determined by the number of heads, because the head capsule is retained longer in its original form than other parts of an insect body. Earthworm numbers were determined from the presence of the anterior (prostomial) ends; this region of the body is highly muscular and is retained longer in its original form than other parts. Arachnid numbers were determined either on the basis of thoracic regions or abdominal regions (whichever was greater). Plant material was determined on the basis of their presence or absence and wherever it was relevant, relative abundance was recorded on an arbitrary scale.

6.3 Food of Black-billed Gulls, Magpies and Starlings

Seasonal occurrence of insects, earthworms and arachnids in Black-billed Gull (L. bulleri), Magpie (G. hypoleuca) and Starling (S. vulgaris) food samples for a thirteen month period is shown collectively in Figure 17; the food composition of each species is appended (see Appendix I). The distribution of Coleoptera, Lepidoptera, Orthoptera and Hemiptera is presented separately while Diptera and Dermaptera, due to their small percentage occurrence, are grouped. In all cases, larval forms of Coleoptera, Lepidoptera, and Diptera (only in January, 1969) are represented on the right hand column of the monthly histogram, while adults and other immature forms are shown on the left.

The results in Figure 17 show a shifting pattern in diet composition according to season and the availability of various groups at different times. The appearance of earthworms during March to September (1968) corresponds with the period



Larval forms
Adult and other immature forms
Tr. = Traces
LUMBRICIDAE
ARACHNIDS
COLEOPTERA
LEPIDOPTERA
HEMIPTERA
ORTHOPTERA
DIPTERA
DERMAPTERA
PERCENTAGE OF TOTAL NUMBERS
20
80
60
40
Tr.
M A M J J A S O N D J F M
1968
MONTHS
1969

Figure 17

Percentage occurrence of earthworms (Lumbricidae), arachnids and insects in Black-billed Gull (*Larus bulleri*), Starling (*Sturnus vulgaris*) and Magpie (*Gymnorhyna hypoleuca*) guts.

when these were present in the top soil. The greatest number were taken during April, when the heaviest rainfall was recorded (see Fig. 15 in Section 5); this had brought the earthworms near the surface, where they were easily picked up by birds. After this period the earthworm portion of bird food remained approximately constant until September. The earthworms were absent from bird gut samples in October. This situation continued till March of the next season. The appearance of earthworms in March (1969) was unusual as they were not represented in the top soil of the majority of the airfield pasture, but were taken from an irrigated portion of the airfield. Drought conditions were experienced during that period which necessitated watering of localized areas (see Plate 14). The presence of sufficient moisture had initiated the movement of soil forms to the upper layer earlier than they would have under natural conditions. Arachnids were represented throughout the sampling period except for July when only traces were recorded.

Among insects, the order Coleoptera was well represented both by adult and larval forms. More larvae than adults were taken from May to September. During this period the larvae of Costelytra zealandica and Aphodius howitti formed the major food species. Adult Coleoptera were more abundant than larvae in bird guts from October, reaching a peak in November, the time when C. zealandica adults were active. Their activity, and also their presence in food samples, started to decrease from December and stopped in January. From late December onward Hypharpax sp., Pyronota setosa, Desiantha maculata and Irenimus aequalis formed the major portion, being succeeded by A. howitti in February and March. Adults of the other species appeared regularly in various months but were in smaller numbers.

The increase of larvae in March (1969) was due to the same factor (irrigation) as already mentioned for the untimely

Plate 14

An area of the airfield under irrigation. Note the accumulation of surface water indicating that the top soil is saturated.

appearance of earthworms during that period.

The order Lepidoptera was mainly represented by larval forms except for the summer months when adults were also present. The adults in food samples during March and April (1968) and November to March (1969) mainly consisted of Crambus sp., Witlesia sp. and Aletia sp.; the first being dominant in March (1968) and January to March (1969) while the other two occurred regularly in samples obtained during summer.

Caterpillars of Crambus sp., Aletia sp. and Agrotis sp. were dominant from April to October. The rise in larval food during January was mainly due to the occurrence of Wiseana cervinata and Coleophora sp. During November and December the lepidopteran contribution to bird diet was less than in other months. This may have resulted from the presence of readily available coleopteran insects during that period.

The order Hemiptera was well represented from December to February. Their numbers were lower in other months and only traces were recorded for September and October. The dominant species were Nysius huttoni and Choerocydnus nigrosignatus which were widely distributed on the pasture, while such species as Rhopalomorpha lineolaris, Dictyotus caenosus, Nysius sp. and Oncocephalus sp. (?) were recorded only in those samples that were obtained while the birds were feeding along the open water channels.

The order Orthoptera was represented during March to June (1968) and December (1968) to March (1969), with traces in July and November. Two dominant species, Nemobius sp. and Phaulacridium marginale, formed the bulk of orthoptera in bird guts, with only small numbers of Conocephalus (Xiphidium) sp. being recorded during January and February. The increased percentage of this order in bird diets from April to June in 1968, was due to the presence of Nemobius sp. and P. marginale. These species at the end of their activity period became lethargic and were thus vulnerable to predation.

The order Dermaptera was regularly represented by the single species Forficula auricularia whose percentage occurrence throughout the investigation period ranged from 0.1 (in December, 1968) to a maximum of 4.4 (in September, 1968).

The order Diptera, with the exception of the January sample, was represented by only adults of the species Anabarrhynchus sp., Sarapogon sp., Sarcophaga milleri, Chironomus sp. and Melanostoma fusciata. The percentage occurrence of these was higher during warmer months (a maximum of 15.0 being recorded in March, 1968) than in winter when they were either absent or only traces were present. The appearance of larval forms of the family Calliphoridae, especially in Starling and Magpie samples in January, was due to the presence of these larvae on sheep carcasses in the area. Starlings and Magpies were regularly seen feeding on and in the vicinity of carcasses during that month.

Besides the above mentioned species, other groups were also represented. In March (1969) two out of ten Magpie guts contained remains of a lizard (probably Leiolopisma sp.) while four contained traces of woodlice (Porcellio scaber). In September (1968) three out of nine Starling guts contained earthworm cocoons that may have been taken from a cultivated portion of the airfield.

Plant materials such as grass blades and clover (Trifolium sp.) leaves were occasionally present in gull and Magpie samples while seeds of peas (Pisum sp.), wheat (Triticum sp.), oats (Avena sp.) and blackberry (Rubus sp.) were present in some Magpies and Starlings during March (1968) and January to March (1969).

6.4 Food of pigeons

Pigeon (Columba livia) samples were obtained during April, August and December 1968, while these birds were feeding on the

Table 14: Food of eighteen Pigeons (*Columba livia*)

Months	No. of birds	Food species				
		Pea	Wheat	Oat	Vetches	Clover
		Pisum sp.	*Triticum* sp.	*Avena* sp.	*Vicia* sp.	*Trifolium* sp.
April 1968	8	2	3	4	1	1
August 1968	4	0	0	0	4	4
December 1968	6	4	0	0	3	2

0 = Absent, 1 = Traces, 2 = Some, 3 = Several, 4 = Many

southern agricultural fields. Results from examination of their crops are presented in Table 14. The food comprised mainly seeds of pea, wheat, oat, vetches (Vicia sp.) and Subterraneum Clover (Trifolium subterraneum). The data in the table is presented on an arbitrary scale ranging from 0-4. These numbers correspond to the amount of each food item, based on absent, traces, some, several and many.

Seeds of Vicia sp. and T. subterraneum were the most consistent food items, being present in sixteen out of eighteen birds, the two specimens in which these were lacking were collected during April. Seeds of Pisum sp. were abundant in December, decreased in April and were absent in August samples. Avena sp. and Triticum sp. were recorded only in the April sample.

6.5 Food of small passerines

During the flocking period of small passerines (December to March) fifteen specimens of Sparrow (P. domesticus), six of Goldfinch (C. carduelis) and six of Greenfinch (Chloris chloris) were obtained. Their food consisted mainly of vetches, Subterraneum Clover, wheat, ryegrass (Lolium sp.), needlegrass (Stipa sp.), cornbind (Polygonum sp.), gorse (Ulex euraeus), dandelion (Taraxacum sp.) and a few other unidentified seeds. In one specimen of Greenfinch two encased caterpillars of Coleophora sp. were also recorded. Since these cases were brownish and elongated they may have been mistaken for seeds.

6.6 Other birds

Nine specimens of Skylarks (A. arvensis) and five of N.Z. Pipits (A. novaeseelandiae) were collected during the course of this investigation. The food comprised mainly of adult and larval insects, arachnids and various plant seeds. Detailed food composition of these species is appended (see Appendix II and III).

Due either to their infrequent occurrence or to smallness of numbers, food of other species was not investigated.

6.7 Discussion

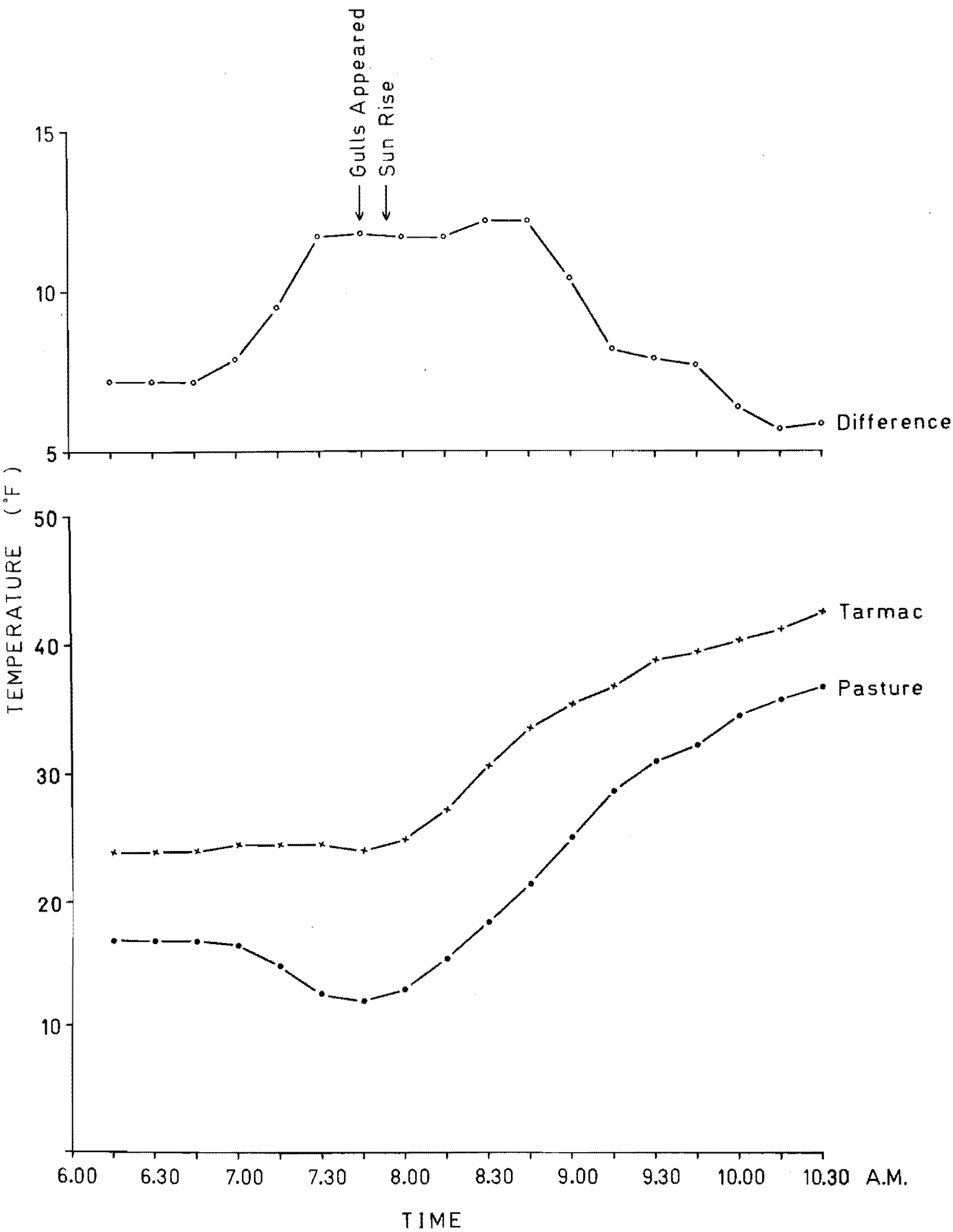
6.7A Food preference and availability

It was noted that individual food differences within a group of a species of insectivorous birds exist. These variations are perhaps the result of individual preferences for a particular type of food which may or may not have been as abundant as others. An assessment based on individual birds would be misleading. However, an examination of randomly collected individuals from the same locality within a limited period, will give an indication of the availability of one or several groups of invertebrates. This can then be compared with the seasonal availability of food species during the period in which bird samples were obtained.

During this study it became apparent that when two or more food species were equally available, the preference for one was marked. This could be a result of the behaviour of the prey species. A dormant form that can stay in a sheltered place is more likely to escape predation than an active species which will reveal itself by either its movement or could be detected by the vibrations of its activity. The importance of sight and hearing in food finding in gulls at least, is documented by Frings, Frings, Cox and Peissner (1955).

6.7B Gulls food and temperature

It is a general belief among aviation personnel that the presence of Black-backed Gulls (Larus dominicanus) at the airfield on cold and frosty mornings is mainly due to the temperature differential between the tarmac of runways and taxiways and the adjacent pasture. During winter these birds arrive in the



Gulls Appeared
Sun Rise
15
10
5
Difference
TEMPERATURE (°F)
50
40
30
20
10
Tarmac
Pasture
6.00
6.30
7.00
7.30
8.00
8.30
9.00
9.30
10.00
10.30 A.M.
TIME

Figure 18

Morning surface temperatures on the tarmac and neighbouring pasture. The difference between the two is shown in the upper graph.

morning from their night roost and settle on the tarmac and its edges. This suggests that the birds are selecting the tarmac because of a temperature difference. Being darker (and due perhaps to some other factors) the tarmac absorbs heat quickly and is slightly warmer than the pasture.

Samolewicz (1964) has, by careful experimentation on Ring-billed Gulls (L. delawarensis), found that they showed selectiveness for surfaces when the temperature difference was 30°F (16.6°C) and over. Using a thermister unit, the temperature difference between the tarmac and the adjacent pasture at Christchurch Airport was observed to reach a maximum of 12.2°F (6.8°C) on 27th July 1969 (see Fig. 18). This differential is not great enough to induce temperature selection in gulls. It is believed that the presence of these birds is due to the presence of food in the form of earthworms. After wet days and nights the earthworms move from the pasture towards the edges of the tarmac which are also filled with run off water. Most of the water recedes after the rain, leaving earthworms on the tarmac. On other occasions the moisture on the tarmac freezes during the night, and earthworms are caught in the ice and are collected by the gulls in the morning. The observations of gulls feeding along the edges of the tarmac during and after rain and the presence of earthworms on such areas support this view.

This contention gets further support from food investigation of the gut contents of twenty Black-backed Gulls, collected while they were feeding on the airfield during March to August 1968. Earthworms formed 100% of the invertebrate food while the only other constituent was grass blades.

7. INSECTICIDE FIELD TRIALS

7.1 Introduction

The study of bird incidence at Christchurch Airport had indicated that the invertebrate fauna of the airfield pasture is one of the main factors influencing bird presence. It was also inferred that the bird numbers could be considerably reduced by controlling invertebrate populations and thereby eliminating food resources. The major invertebrate population falls into three classes, the Insecta, Oligochaeta and Arachnida, of which the first two are major constituents of bird food, while the third is of lesser importance. Control and/or elimination of these groups could be best achieved by chemical means. For this purpose an "insecticide" trial programme was undertaken, mainly to determine the efficacy of some reputed soil chemicals under local conditions. The situation required the use of a chemical with a wide range of activity. The available information of the activity spectrum of potential insecticides is extensive but since the environmental conditions of the area to be treated greatly influence their result it was necessary to field test them. With these considerations in view, three insecticides were tried on an experimental plot at the airfield pasture.

7.2 The insecticides

The insecticides used were: (a) "Telodrin" (1, 3, 4, 5, 6, 7, 8, 8 - octachloro - 3a, 4, 7, 7a - tetrahydro - 4, 7 - methanophthalan) a "Shell" product; (b) "Dasanit" (0,0 - diethyl - 0 - (4 - methylsulfinyl - phenyl) - monothiophosphate) a "Bayer" product; and, (c) "Gesapon" (= "Diazinon") (0,0 - diethyl - 0 - (2 - isopropyl - 4 - methyl - pyrimidinyl (6) phosphorothiate) an "Ivon Watkins-Dow" preparation. Gesapon and Dasanit (both organophosphates) are short residual

Plate 15

A short term pit trap made of an "Agee" jar and an inner plastic pot.

insecticides (Kain and Christie, 1966) while Telodrin (a chlorinated hydrocarbon) has been reported to be active as a soil insecticide for at least five months (Shell technical information on Telodrin). These insecticides are reputed to possess a wide range of activity as contact and stomach poisons both on the surface and in the soil.

7.3 Trial plot

A trial plot was selected at the south-east end of the subsidiary runway close to the experimental area "A". The area was uniformly flat; slopes were avoided while selecting the trial plot because of chance of possible chemical mixing due to run off water from one sub-plot to another, thus affecting the chemical concentrations in the respective sub-plots.

The plot was one chain square, divided into sixteen 16'6" x 16'6" sub-plots. Random replicates based on latin squares were selected from Cochran and Cox (1957) for each treatment (see Fig. 19). The insecticides were applied on four random replicates per treatment with four untreated control sub-plots. Two pit traps, consisting of "Agee" jars (see Plate 15) with inner plastic pots, were placed at ground level in each of the sixteen sub-plots. Their aim was to evaluate control of surface forms. A few small holes were provided at the bottom of the plastic pot to allow water to go through. The water thus collected in "Agee" jars was sucked out with an aspirator.

7.4 Form and method of application

All insecticides were applied in granulated form (5% formulations) at a rate of 2lb active ingredient per acre. Formulations of Dasanit and Gesapon were readily available through the courtesy of respective manufacturing companies while Telodrin was available as active ingredient from Shell Oil

Aa	Ba	Ca	Da
Bb	Db	Ab	Cb
Cc	Ac	Dc	Bc
Dd	Cd	Bd	Ad

Aa – Ad	'TELODRIN'
Ba – Bd	'DASANIT'
Ca – Cd	'GESAPON'
Da – Dd	CONTROL

Figure 19

Diagram of the insecticide trial plot, showing replicate distribution.

(N.Z.) Limited. The Telodrin formulation was, however, available through the co-operation of Farm Chemicals, Nelson.

The granulated formulations were preferred because of several advantages. Insecticides in this form can be easily applied without using sophisticated spraying units and the application can be made under moderate wind conditions; it also gives an even and easy spread of chemicals on the subplots without chances of chemical overlapping, and above all it is a lot safer to handle granules than other forms.

The treatment was delayed during autumn (1969) due to continued dry weather. During that period the plot was occasionally saturated by a mobile unit to initiate grass growth. A good ground cover was considered desirable to help in evaluation of possible chemical effects on the vegetation and its subsequent growth in the long term.

The insecticides were applied by using a four ounce "Coffee jar" with a perforated lid. While handling insecticides, besides other precautions, a "Protector Aspirator" with dual filtering cartridges was used.

7.5 Sampling design

Three soil cores (each 2.5" diameter and approximately 3.5" deep) were randomly taken from each sub-plot to determine the number of subterranean forms. Pre-treatment samples were obtained on the day the area was treated. Post-treatment samples, to determine the extent of control, were obtained one week, two weeks, four weeks, eight weeks, twelve weeks and eighteen weeks after treatment.

The soil cores were kept separately in numbered plastic bags and were independently examined in the laboratory. Each core was crumbled in a tray and the visible forms were collected, the soil was then sieved through a set of four sieves (see Methods) and the animals collected. The plant material was

Table 15: Results of insecticide trial at Christchurch Airport
Date of treatment: 27-5-1969

Time of sample	Treatment	Coleoptera	Lepidoptera	Diptera	Lumbricidae
		Soil inhabitants			
Pre-treatment	(Telodrin)	8	3	2	11
	(Dasanit)	9	3	3	10
	(Gesapon)	7	5	2	7
	Control	9	2	2	9
One week after	Telodrin	1	0	1	0
	Dasanit	2	1	2	4
	Gesapon	4	3	2	6
	Control	8	2	2	8
Two weeks after	Telodrin	1	0	0	0
	Dasanit	2	2	1	3
	Gesapon	2	0	1	5
	Control	8	3	3	9
Four weeks after	Telodrin	1	0	0	0
	Dasanit	3	0	1	4
	Gesapon	4	0	1	6
	Control	9	2	2	10
Eight weeks after	Telodrin	1	0	1	0
	Dasanit	3	0	2	5
	Gesapon	5	0	0	6
	Control	7	1	4	11
Twelve weeks after	Telodrin	0	0	1	0
	Dasanit	4	0	1	4
	Gesapon	4	0	2	5
	Control	8	2	2	10
Eighteen weeks after	Telodrin	0	0	1	0
	Dasanit	3	0	2	0
	Gesapon	3	0	1	0
	Control	6	1	3	0

then subjected to Tullgren type extraction.

A two foot peripheral area inside of each sub-plot was avoided for post-treatment sampling because of possible border line chemical interactions from adjacent sub-plots.

Before the treatment, animal counts on a 24 hour basis were made in the pit traps to get an indication of the activity of surface dwelling forms. This was followed by four post-treatment checks after five, ten and fifteen days of treatment.

7.6 Results

The effect of chemicals on numbers of earthworms (Lumbricidae) and larvae/caterpillars of Coleoptera, Diptera and Lepidoptera (per twelve soil cores) before and after the treatment is shown in Table 15.

In both pre- and post-treatment samples the numbers represent only living and healthy specimens. Coleopteran larvae included members of the families Scarabaeidae, Carabidae, Elateridae and Curculionidae; Diptera was represented by the families Asilidae, Tipulidae and Therevidae, of which only one specimen was recorded in the controls, eight weeks after treatment; Lepidoptera was represented by the family Noctuidae.

In post-treatment samples of the Telodrin and Dasanit treated areas, the Coleopteran larvae belonged only to the family Curculionidae while in the case of Gesapon a few larvae of Scarabaeidae were also recorded. The Curculionidae larvae were about 0.125" long and probably moved very little and hence may have escaped contact with the chemicals. The disappearance of earthworms from the last sample (eighteen weeks after treatment) was due to their absence in the top soil during that period.

The results indicate that a significant control of the majority of soil inhabiting animals was possible through the application of Telodrin, while Dasanit and Gesapon were not as effective (Wilcoxons Rank-Sum Test, $0.001 \leqslant P \leqslant 0.005$; test

Table 16: Results of insecticide trial at Christchurch Airport
Index of activity in pit traps for 24 hour period

Time of sample	Treatment	Coleoptera	Hemiptera	Orthoptera	Araneida & Opiliones
Pre-treatment	(Telodrin)	4	2	0	11
	(Dasanit)	5	1	0	8
	(Gesapon)	5	1	0	10
	Control	4	1	0	10
Five days after	Telodrin	3	1	2	4
	Dasanit	3	0	1	6
	Gesapon	3	0	1	7
	Control	5	1	1	9
Ten days after	Telodrin	1	0	1	3
	Dasanit	2	0	1	4
	Gesapon	1	0	1	5
	Control	4	0	0	6
Fifteen days after	Telodrin	1	0	2	2
	Dasanit	2	0	1	4
	Gesapon	2	0	1	4
	Control	4	2	0	5

based on Coleoptera and Lumbricidae).

The activity of surface dwelling Coleoptera, Hemiptera, Orthoptera, Araneida and Opiliones showed a significant decrease on the treated plots after ten days of treatment (see Table 16).

The adult Coleoptera recorded in pit traps belonged to the families Curculionidae and Carabidae while Elaterids were rare. Hemiptera was represented by Nysius huttoni only while Arachnids mainly belonged to Araneida with occasional Opiliones. The Orthoptera (especially Nemobius sp.) in post-treatment samples were recorded only from the treated sub-plots. The occurrence of one specimen of Phaulacridium marginale in the controls may have been due to its movement from treated sub-plots after taking a lethal dose of chemicals. These two species when healthy could move out of the pit traps. Their presence in post-treatment samples, however, suggests that their activity was either checked due to poisoning or may have resulted from the fact that the period coincided with the end of seasonal activity of these species. Few dead female moths of Atomotricha sp. were recorded on the Telodrin treated area. The occurrence of these in pit traps due to the poisoning is doubtful because the females are brachypterous and their presence there may have been accidental.

7.7 Test for microorganisms

The role of soil microorganisms in the decomposition of organic matter is well established (see Waksman and Starkey, 1931; Ferguson, 1957). In view of the similar role played by earthworms (Lumbricidae) (see Satchell, 1967), and the necessity of their elimination from the airfield pasture to reduce bird food sources, the importance of microorganisms is greatly enhanced.

In November 1969 experiments were conducted to determine the after-effects of the three insecticides on the numbers of microorganisms (Nematodes, Protozoa, Bacteria, Fungi and Algae) in comparison to the untreated area (control).

Four soil cores, each 1" (2.54 cm) diameter and 3" 7.62 cm) deep, were taken from each of the sixteen replicates. The cores from individual replicates were carefully crumbled and thoroughly mixed. The soil was then divided into four equal parts, one of which was used for analysis. Since it was expedient to examine microorganism populations only superficially, the simplest methods for determining the desired information for each group was adopted. No attempt was made to identify these organisms and the assessments were based on either absolute numbers (individuals or colonies) or on an arbitrary scale.

7.7A Nematodes

For nematode counts 30 grams of soil from each replicate was separated and subjected to Baermann funnel extraction. After 48 hours, 200 ml of bottom extract from each funnel was removed. Nematodes, being heavier than water, slowly move towards the bottom (Peters, 1955). The extract was then allowed to settle before excess water was removed, and the concentrate was transferred to a petri dish held on a stand with 1 cm square markings on it. Nematodes were counted from ten random squares for each replicate. The results from four treatments are shown in Table 17, which suggests that the numbers were least affected by Telodrin treatment and most by Dasanit, while the effects of Gesapon were intermediate.

Table 17: Number of Nematodes per gram of soil for each treatment

Treatment	No. of nematodes
Telodrin	39
Dasanit	12
Gesapon	28
Control	45

7.7B Protozoa, bacteria, fungi and algae

To determine the effects of treatment on protozoa, bacteria, fungi and algae, standard culturing methods were employed. The first three were cultured on agar plates while the fourth was cultured in test tubes with algal culture media. Standard soil dilutions of 1/10, 1/100, 1/1,000, 1/10,000 and 1/100,000 were prepared for each replacate by mixing 10 grams of soil with 90 ml of sterile water.

I. Protozoa

Protozoa were cultured in petri dishes on the media (see Appendix IV) described by Pramer (1965). Two plates each for 1/10, 1/100 and 1/1,000 dilutions were inoculated with 1 ml of inoculant. The plates were kept at room temperature for six days, under normal daylight conditions, before examination. The abundance of the classes Rhizopoda, Ciliata and Flagellata was determined in each plate (1/10 and 1/100 dilutions) on an arbitrary scale (1-3) based on present, common and abundant (see Table 18). The results do not indicate any effect of treatment. Besides the three classes of protozoa, a few rotifers and tardigrades were also present.

Table 18: Abundance of protozoa in each treatment

Treatment	Rhizopoda	Ciliata	Flagellata
Telodrin	1	3	2
Dasanit	1	3	2
Gesapon	1	3	2
Control	1	3	2

1 = Present
2 = Numerous
3 = Abundant

II. Bacteria

Bacterial presence was determined on agar plates containing "Difco Bacto Nutrient Agar" media (see Appendix V). Two plates were inoculated by 1 ml inoculum of 1/1,000, 1/10,000 and 1/100,000 dilutions for each replicate. Aseptic precautions were taken during inoculation. The plates were incubated at room temperature. For colony counts each plate was divided into eight equal parts and the number of colonies was determined from two such divisions. The counts were made after three days of inoculation from plates of 1/10,000 and 1/100,000 dilutions. Results based on mean plate counts for each treatment are shown in Table 19. Bacterial colonies for Dasanit treated area were less than the ones in either Telodrin or Gesapon while those from control were the highest.

Table 19: Number of bacterial colonies per plate (area 56.8 cm^2) for each treatment

	Treatment			
	Telodrin	Dasanit	Gesapon	Control
No. of colonies	486	331	519	579

III. Fungi

The presence of fungi was determined by culturing two plates of 1/1,000, 1/10,000 and 1/100,000 dilutions for each replicate, while using "Potato Dextrose Agar" media (see Appendix VI). Plates were inoculated with 1 ml of inoculum under aseptic conditions and then incubated at room temperature. The colonies were counted in the same way as for bacteria from plates of 1/10,000 and 1/100,000 dilutions. These counts (see Table 20) show a slightly higher number for Telodrin than for the control while counts for Dasanit and Gesapon were lower.

Table 20: Number of fungal colonies per plate (area 56.8 cm^2) for each treatment

	Treatment			
	Telodrin	Dasanit	Gesapon	Control
No. of colonies	109	96	70	101

IV. Algae

To determine the presence of algae, test tubes containing 10 ml of inorganic salt solution (see Appendix VII), were inoculated with 1 ml inoculum of 1/10 and 1/100 dilutions for each replicate. Two replicate tubes of each dilution were used and the presence of algae and its relative growth was determined six months after inoculation. The tubes were kept at room temperature under normal day and night light conditions.

The amount of algal growth was assessed for each treatment (see Table 21) on an arbitrary scale (1-4) based on present, few, many and most.

Table 21: Index of algal growth in each treatment

	Treatment			
	Telodrin	Dasanit	Gesapon	Control
Amount of growth	3	4	2	2

1 = Present
2 = Few
3 = Many
4 = Most

Algal growth was enhanced in samples from Dasanit treated area, Gesapon and the control were at the same level while Telodrin occupied an intermediate position.

7.8 Effect on vegetation and soil texture

None of the insecticides appeared to effect the ground cover in the plot as the vegetation remained green (see Plate 16) till the start of summer and showed no signs of growth retardation. The soil texture had, however, changed slightly due possibly to the binding effect of chemicals on soil particles. The soil cores from the treated areas were reasonably compact and held their form better than the ones from the control area.

7.9 Conclusion

Of the three insecticides tried, only Telodrin showed sufficient toxicity to control the majority of the meso and macrofauna. Accordingly the infauna of the airfield pasture could be considerably reduced by the application of Telodrin at the rate of 2lb of active ingredient per acre. This would help in eliminating a major attraction factor (food) from the airfield for some of the hazardous bird species.

Although the number of meso and macrofauna will be greatly affected, the number of microorganisms will not be altered to

Plate 16

General view of the insecticide trial plot after twelve weeks of treatment. In the foreground is one of the "Telodrin" treated sub-plots.

any large extent. There is no information on the effects of this chemical (Telodrin) on microorganisms at the time of treatment, but the trial carried out six months after treatment suggests that the effect, if any, was not persistent.

8. GENERAL RECOMMENDATIONS AND CONCLUSION

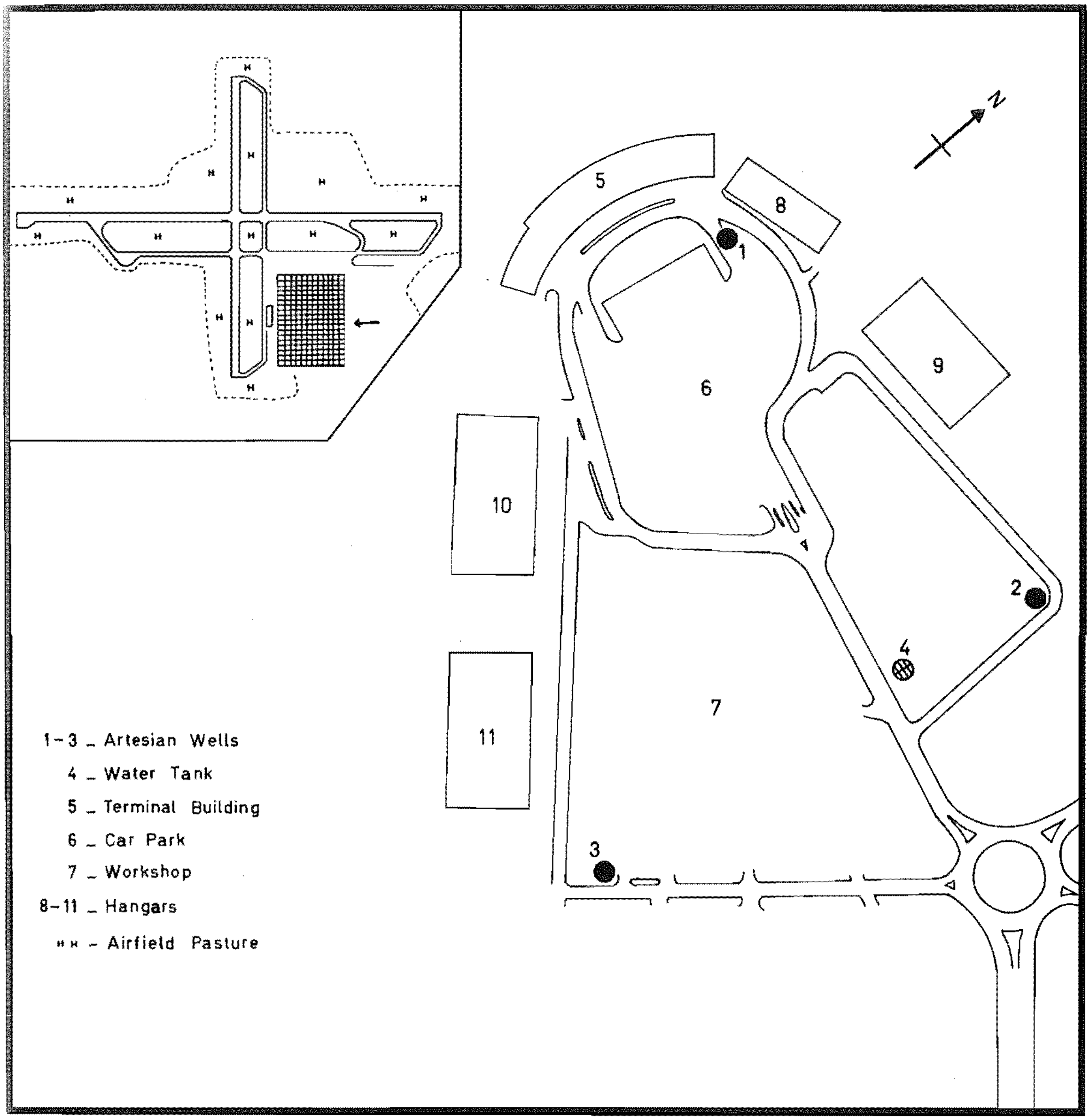
8.1 Introduction

The variety and numbers of birds on Christchurch Airport is largely dependent upon the availability of food on and about the airfield. As long as the present conditions persist, birds will continue to exploit this food source. The following recommendations are put forward to help make the airfield and its environs "unattractive" to birds, and thus reduce their incidence to a safer level.

8.2 Insecticide treatment

The use of Telodrin at the rate of 2lb active ingredient per acre in 5 % granulated form during autumn (preferably in April), when the ground is sufficiently moist, will provide an effective control against the majority of infauna. Better results will be obtained when rain is expected within 24 hours of treatment (J.M. Kelsey, pers. comm.). The advantages of this being; (a) that under moist conditions, most of the soil fauna inhabit the top few inches; (b) the chemical will stand a better chance of coming in contact with the invertebrates in a maximum concentration; and, (c) rain after the treatment will wash the chemical from the carrier granules and will help its diffusion into the sub-surface soil layers.

Telodrin is a toxic insecticide (acute oral $L.D_{50}$ to rats, 7mg/kg of bodyweight) with a prolonged residual effect, therefore, extreme care should be taken while handling, which should be done by knowledgeable hands. It seems that the only disadvantage of using this chemical will be the chances of possible contamination of the airport's water supply. The Airport Authority maintains its own water supply through artesian wells situated within the airport establishment (see Fig. 20). Although it is most unlikely that the washed-off chemical from



N
5
8
1
6
9
10
2
4
7
11
3
1-3 _ Artesian Wells
4 _ Water Tank
5 _ Terminal Building
6 _ Car Park
7 _ Workshop
8-11 _ Hangars
ʜ ʜ - Airfield Pasture

Figure 20

Location of the artesian wells in relation to the airport establishment and the airfield pasture. Inset depicts the location of enlargement.

the top layer of the airfield pasture will come into contact with artesian water, any such possibility should be considered before creating a health hazard.

The insecticide residues do not normally penetrate far below ground. Any accumulation is reported to be confined chiefly to the top twelve inches of soil, and within this depth greater concentrations have been noted within 4-6" of the surface (Rudd, 1964). Whereas Barthel, Murphy, Mitchell and Corley (1960) have reported residue concentration of heptachlor in the top inch of soil. In the light of these facts it is most unlikely that the chemical will contaminate artesian water. After treatment of the pasture, frequent analysis of artesian water should be conducted as an extra precautionary measure against possible chemical contamination.

Initially it will be necessary to treat all pasture within the operational boundary. At a later stage, systematic treatment of the bordering areas in the north and south of the main runway and the area in between Harewood Golf Course and the operational boundary may become necessary. This should, however, be curtailed until results from the first treatment are available.

At present hay is harvested alongside the main runway on the southern airfield pasture. Harvesting will have to cease for at least six months after the treatment and also the first harvest after six months will have to be avoided as stock feed unless a permission from the Department of Agriculture is obtained.

Birds should be discouraged from feeding on the pasture immediately after the treatment because they could feed on poisoned invertebrates and secondary poisoning may result.

8.3 Cultivation

Cultivation of the airport area should be reduced to the least possible level because cultivated fields attract large flocks of birds. Lucerne (Medicago sp.) would appear to be the best crop to grow as this does not require as much ground tilling as other crops. Whenever cultivation is necessary a person with a Very pistol or a shotgun should be posted in the area to discourage birds from settling. Occasional checks on subsequent days may be necessary to discourage stray birds because they may act as decoys for others.

Cultivation can also be co-ordinated with the time (in summer) when the soil animals are deeper. This will of course be difficult as the ground will be hard to cultivate, but this practice can be applied when a smaller area is involved. If practical this procedure may be of some benefit in reducing numbers of soil invertebrates due to the exposure of these animals to unfavourable climatic conditions.

8.4 Cropping

At present it is a normal practice on the agricultural fields next to the southern operational boundary to alternate pasture with crops of wheat, oat, pea, clover and occasional turnip (Brassica sp.) and potato (Solanum sp.). Its economic importance can not be questioned, but seeds from the grain crops that fall on the ground attract large numbers of seed-eating birds while turnip and potato plants harbour Lepidopteran caterpillars that are preyed upon by insectivorous birds.

Birds feeding on these areas are no problem, but they invariably are put to flight by plane movements and thus create a dangerous situation for aircraft using the main runway. Reduction in cultivation of crops that are used as stock feed and attract birds, directly or indirectly, is recommended. Hay cropping on such fields may be a worthwhile alternative.

8.5 Stock keeping

Birds, especially Starlings, are commonly seen feeding along with stock. This association is perhaps advantageous to birds in that the insect fauna of the pasture is disturbed (by stock movement). They are thus exposed to possible predation and the birds take this opportunity to feed on the easily accessible prey. This phenomenon is more pronounced on areas with long ground cover than on zero grazed pasture.

At Christchurch Airport, sheep are grazed on pasture adjacent to the operational boundary. This practice requires some re-thinking because bird concentrations on these areas along with stock are dangerous. Zero grazing and a constant look-out for bird concentrations during the period when stock is in the area will help in reducing the chances of birds coming into the line of aircraft flight.

8.6 Co-ordination with agricultural practice

During autumn and spring some of the agricultural fields surrounding the eastern, southern and south western part of the operational boundary come under cultivation. Thus large flocks of gulls and Starlings are attracted to feed on earthworms, Coleopteran and Lepidopteran larvae and Dermaptera that are so exposed. This land is either on lease from the Airport Authority or owned by individual farmers. Some of these people are reluctant to disperse birds from their fields but at the same time they are aware of the potential danger to aviation created by these birds. The farmers might not do anything to disperse birds but they may help the airport management in doing so if a liaison could be established. Farmers can be requested to inform the airport management whenever cultivation is to be undertaken so that bird dispersal measures can be implemented. This information when passed on to airport control, will help in flight planning as flight control personnel will be aware of possible bird concentrations on specified areas.

8.7 Co-operation between airport control and maintenance

Birds fail to form large flocks if the early arrivals are discouraged from remaining in the area. Continued co-operation between airport control and the maintenance personnel will help in dispersing early arrivals. Airport control personnel in the control tower can be requested to keep a constant look-out for flocking on and in the vicinity of the airfield. Whenever necessary either they themselves should disperse these early arrivals or else inform the airport maintenance to do so. This has been normal practice during the last few years and its continuance will not be difficult.

The birds thus dispersed leave the area immediately, but on occasions reappear after an hour or so. For this reason an hourly patrol of the area during the subsequent two or three hours will be advisable to make sure that the birds have actually left the area and settled elsewhere.

8.8 Grass cover

Long grass has been recommended as a bird deterrent (Cook-Smith, 1963; Caithness et al., 1967; Saul, 1967; Wright, 1968). Maintenance of a long and thick ground cover, especially on the approaches to the runways, will help in discouraging birds from settling there. Areas of thin ground cover may need seeding and fertilizing to encourage thick growth. Long but thin cover does not discourage birds but certainly obscures them from being detected by airport control.

On many previous occasions the grass has been cut to almost ground level but general practice now is to mow at 2-3". There should not be any difficulty in adjusting the height of the mowers presently in use, to leave a sward of 4-6" which should be maintained throughout the year.

Timing the pasture mowing during summer to the period before seeding and the early stage of flowering will help in reducing the food supply of smaller passerines like Sparrows, Goldfinches and Greenfinches.

8.9 Water channels

At present two open water channels run across the pasture north and south of the main runway. Starlings, Magpies and occasionally White-faced Herons, ducks and Banded Dotterel were seen feeding along these channels. Because of the moisture a luxuriant growth persists throughout the year and provides a habitat for a number of insects, mainly long-horned grasshoppers (Conocephalus (Xiphidium) sp.) and various Hemipterans such as Nysius sp., Dictyotus caenosus, Rhopalomorpha lineolaris and others. Closing of these channels is necessary to prevent birds from feeding on these areas.

8.10 Starling nesting places

It has been observed that during the breeding season Starlings nest within the airport establishment. These birds represent the local population that feed on the airfield pasture. Although not present in great numbers, they act as decoys to attract more individuals of the species from adjacent populations, especially outside the breeding season.

Common nesting places occur in the hangars, various barracks and houses. A thorough search for these nesting places at the start of the breeding season and subsequent removal of nests and screening of the entrances will be necessary to check further increases in the resident populations.

8.11 Pesticide control of birds

8.11A Control of Starlings

The existing resident Starling population can be controlled by systematic poisoning, using pelleted bait of DRC 1339 (= AC 47,676). DRC 1339 (3-Chloro-p-toluidine hydrochloride) was found to be an effective means of Starling control (De Cino, Cunningham and Schafer, 1966; Besser, Royall and Degrazio, 1967; Royall, De Cino and Besser, 1967; West, 1968). Although commercially produced in the United States, this chemical is not internationally distributed. However, 25 lb of 1% pelleted bait has recently been obtained for experimental purposes (through the courtesy of The Cyanamid International of Princeton, New Jersey).

Pelleted baits are expected to be useful on a limited scale and on specific feeding areas. Its large scale use at Christchurch Airport is doubtful because Starling flocks feeding on the airfield pasture show a reluctance to eat grain food; this was evident after an alpha-Chloralose ($C_8H_{11}O_6Cl_3$) trial. Alpha-Chloralose has been successfully used to control a Black-backed Gull (_L. dominicanus_) colony (see Caithness, 1968b, 1969). Alpha-Chloralose was tried on the airfield pasture by mixing it with boiled wheat. Boiling was carried out to obtain a sticky surface on the grain which would hold the powdery chemical. In order to get a 2% formulation (by weight), 50 g (1.76 oz) of chemical was thoroughly mixed with 2500 g (5.51 lb) of wheat. The treated wheat was applied in six rows of 30 yards each at four yard intervals on the pasture which Starlings were regularly visiting. Rows of untreated wheat were alternated with treated ones. On three occasions flocks of about 300 Starlings were observed on the treated area. Observations suggested that the birds were not taking the grain which was confirmed when the area was examined later. This reluctance to eat grain, it seems, was due to the availability of invertebrate food on the area.

8.11B Control of Black-backed Gulls

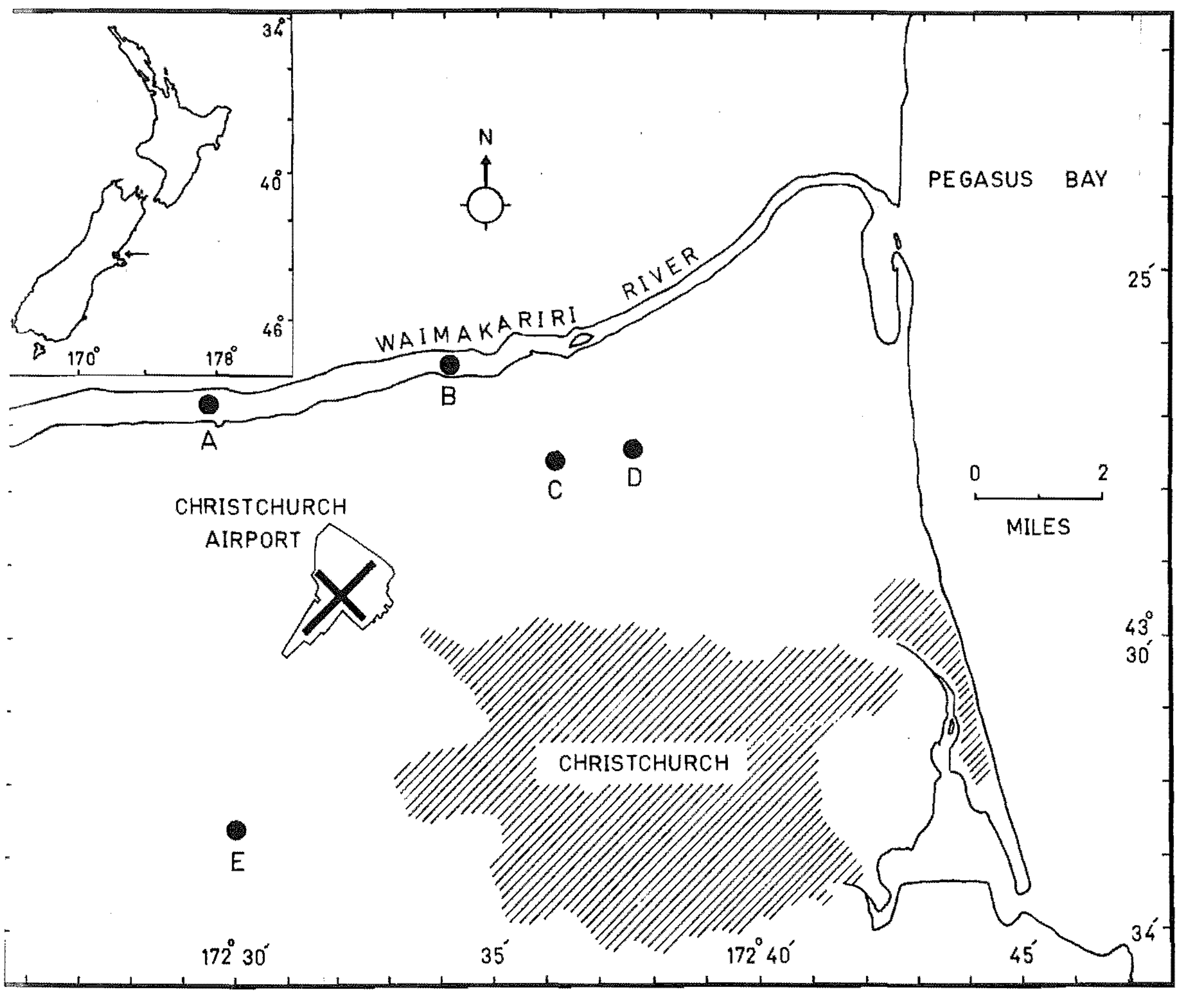
Black-backed Gulls (L. dominicanus) from two roosts in the Waimakariri river bed frequent the airfield and its environs. Birds from the Colony X (estimated 3,000 to 4,000 birds) roost (and possibly nest) to the north east of the airfield while the Colony Y (estimated 2,000 to 3,000 birds) roost and nest to the north east (see Fig. 21). Members of the first colony move daily between the roost and the Islington Freezing Works (see Plate 17) while major flights from the second take place on the eastern side in between the roost and the Belfast Freezing Works and Waimairi Council's rubbish dump.

Birds from these colonies will not use the airfield for feeding, once they are denied a source of food. However, if these colonies are left alone, flocks will continue to fly over the airfield. In that case it will be necessary to systematically reduce the numbers in the two colonies to a low level. This process can be carried out in the same way as already in operation at Napier (see Caithness, 1968b, 1969).

During the 1969-70 breeding season about 250 nests were located on the Colony Y three miles north east of the airfield. Aircraft using the main runway flew directly over the nesting birds. At that distance from the airfield the aircraft were at an altitude at which they were not endangered by the birds. Occasionally during the post-breeding period dangerous situations, however, arise when these birds move inland towards the airfield for feeding.

8.12 Disposal of stock carcasses

Disposal of dead stock from the agricultural fields is



34°
40°
46°
170°
178°
N
PEGASUS BAY
WAIMAKARIRI RIVER
25′
A
B
C
D
0
2
MILES
CHRISTCHURCH AIRPORT
43° 30′
CHRISTCHURCH
E
34′
172° 30′
35′
172° 40′
45′

Figure 21

Location of roosts and major feeding grounds of Black-backed Gulls (*Larus dominicanus*).

A. Roosting colony X
B. Roosting colony Y
C. Waimairi Council's rubbish dump
D. Belfast Freezing Works
E. Islington Freezing Works

Plate 17

Black-backed Gulls (*Larus dominicanus*) feeding at the Islington Freezing Works refuse pit. These birds fly across the aircraft flight paths at dusk to reach their nocturnal roosts.

suggested as the carcasses attract birds that feed on fly maggots of the family Calliphoridae. Flocks of 20 to 30 Starlings, and up to four Magpies, were noted occasionally on sheep carcasses.

8.13 Clearing of shrubs

Shrubs have recently been cleared from the area between Pound Road (on the west of the airfield) and the operational boundary of the southern end of the main runway. A small area on the approaches to the eastern end of the subsidiary runway still remains to be improved because small passerines normally rest in such places between feeding bouts.

8.14 Conclusion

The record of bird strikes and near misses to aircraft at Christchurch Airport from June 1965 to March 1970 (see Table 22) suggests that most incidents occur while aircraft are in the final stages of landing or taking off.

Table 22: Percentage of bird strikes and near misses at Christchurch Airport from June 1965 to March 1970 at various stages of flight regime. N = 159.

	Flight regime	Percentage
1.	Take off	46.54
2.	Landing	20.75
3.	Touchdown	5.03
4.	Taxi-ing	1.25
5.	Final approach and short final	25.15
6.	1,000 feet after take off	1.25

These figures indicate that at least 73.5% (and perhaps more) strikes and near misses occurred (1 to 4 in table) while the aircraft were at stages of their flight regime that takes place within the airport's operational limits or at the most within a 1.5 mile radius along the approaches to the runways (see Fig. 22). While in search of food or feeding in the area, birds usually fly at heights of less than 300 feet. Normal climb out altitudes after take off for Viscount and DC-8 aircraft are shown in Figure 23. Other jet aircraft normally follow the same pattern as the DC-8 while propeller driven aircraft would have a pattern similar to that of the Viscount. This suggests that the aircraft are usually at a safer altitude beyond one mile after take off, because at that distance bird concentrations are expected to be at lower altitudes than those used by aircraft (especially after take off). If the birds are successfully kept away from within 1.5 miles of the approaches to the runways, the possibility of bird strikes and near misses to aircraft can be considerably reduced (up to 73.5%). It is hoped that the application of methods suggested to reduce bird numbers, will help to achieve this goal.

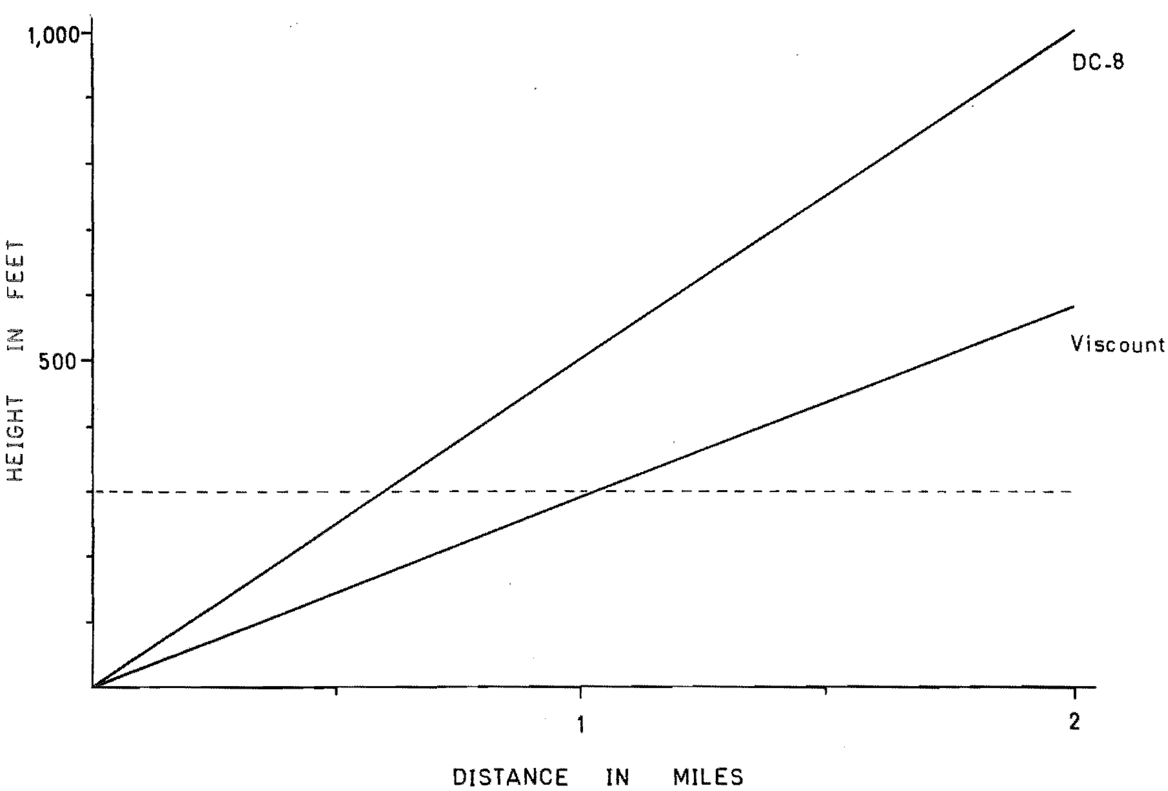

1,000
500
HEIGHT IN FEET
DC-8
Viscount
1
2
DISTANCE IN MILES

Figure 22

Climb out flight paths of DC-8 and Viscount aircraft (derived from Associate Committee on Bird Hazards to Aircraft, National Research Council, Canada, Field Note 30). The broken line indicates the estimated maximum height of bird flights on and about the airfield.

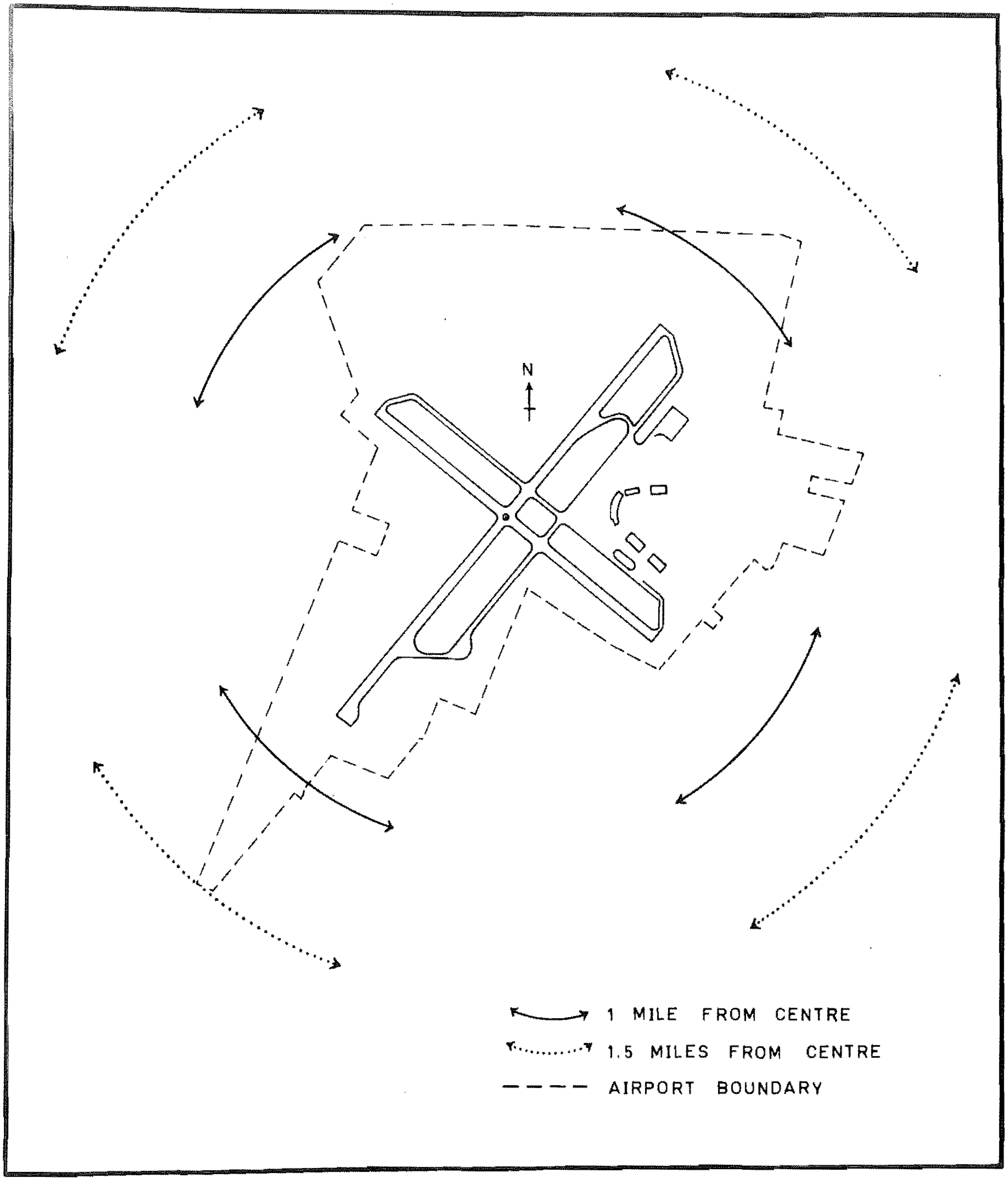

N
1 MILE FROM CENTRE
1.5 MILES FROM CENTRE
AIRPORT BOUNDARY

Figure 23

Location of 1 and 1.5 mile radial limits about Christchurch International Airport.

SUMMARY

1. The problem of birds as hazards to aircraft is reviewed in a world-wide context. Recent research has indicated that solution of the problem could be approached by two main methods: (a) by protecting vital aircraft components through mechanical means against bird strike damage; and, (b) by reducing the number of birds (and hence strikes) at airports through ecological methods.

Since aircraft manufacturers have not, as yet, developed aircraft that can totally withstand bird strike damage, this study sought to evaluate ecological methods for reducing the incidence of birds at Christchurch International Airport.

2. The general nature of bird hazards on and about airfields in New Zealand is described. Specific aspects of the problem at Christchurch Airport are evaluated in detail under appropriate headings.

3. A total of nineteen bird species were observed on the airfield. Species composition, seasonal fluctuation in numbers and also daily and seasonal movements in relation to their relative "hazardness" is given. These birds either fed and roosted on the airport or flew over or close to it so as to intersect the aircraft flight pattern while the latter were using the airfield. The occurrence of large flocks of Starlings and Pigeons on and in the vicinity of the airfield is described and related to farming activities in the area.

4. Species composition, seasonal distribution and abundance of various food species of birds (invertebrates in particular and plant material in general) was assessed in relation to their availability. Of the invertebrates, ten insect orders (Coleoptera, Lepidoptera, Diptera, Dermaptera,

Orthoptera, Hemiptera, Hymenoptera, Odonata, Procoptera and Collembola), earthworms (Lumbricidae) and arachnids (belonging to orders Araneida and Opiliones) were represented. Plant seeds were available to birds either on the farmlands after harvesting or on the airfield pasture during and after seeding.

5. Seasonal trends in the diet of some hazardous bird species were determined and then related to food availability in the field. It was found that predation of food species was dependent upon their availability. Marked preferences for specific foods were noticeably absent except in the case of Black-backed Gulls which fed exclusively on earthworms.

6. Since it was established that the presence of birds on or about the airfield was due to an abundance of food, chemical control of invertebrate food species was attempted. A chemical trial was conducted to determine the effectiveness of three reputed "insecticides" ("Telodrin", "Dasanit" and "Gesapon") in controlling the invertebrate forms. "Telodrin" was found to be most effective for controlling the majority of invertebrate forms, whereas both "Dasanit" and "Gesapon" showed a narrower range of control.

7. In view of the importance of soil microorganisms in the decomposition of organic matter an attempt was made to determine the effects of "insecticides" on microorganisms (Nematodes, Protozoa, Bacteria, Fungi and Algae). Results of these determinations showed that six months after application the abundance and diversity of microorganisms was not affected to any appreciable extent.

8. The following recommendations are aimed at reducing

the incidence of birds at and about the airfield: (a) treatment of the airfield pasture with "Telodrin" at the rate of 2 lb active ingredient per acre to reduce invertebrate populations; (b) population control (by poisoning) of Black-backed Gulls and Starlings; (c) restricted agricultural practice in adjoining farmlands, especially cultivation and grain-cropping; (d) retention of a deep sward of grass on the airfield pasture; (e) clearing the shrubs from the runway approaches; (f) closing of two open water channels at the northern and southern end of the main runway; (g) removal of Starling nest sites from the airport buildings; (h) disposal of sheep carcasses from the immediate vicinity of the airfield; (i) restriction of stock from areas near the runways and its approaches; (j) closer co-operation between airport control and airport maintenance in discouraging birds from flocking on and about the airfield; and, (k) co-ordination of agricultural activity on the surrounding farmlands and the airport management.

9. It is concluded that if the birds are successfully discouraged from within a 1.5 mile radius of the airfield's approaches, a considerable reduction (up to 73.5%) in bird strikes and near misses can be achieved.

ACKNOWLEDGEMENTS

My sincere thanks are due to my supervisors, Professor G.A. Knox and Dr W.C. Clark, for encouragement and helpful advice throughout the period of this study and for suggestions and criticism on the manuscript. In this respect I am also especially grateful to Dr B. Wisely.

Thanks are also due to various members of the teaching and technical staff, and research students of the Zoology Department, University of Canterbury, in particular to Messrs K.W. Duncan, A.J. Baker, F.H. Wood, J.D. Coleman, R.A. Galbreath, R.H. Thompson, J.T. Kay and A. Gall for their timely help on many occasions.

Throughout the period of field work helpful co-operation was received from Messrs A.I.R. Jamieson (the Airport Manager), J.R. Claydon (the Assistant Airport Manager), V.E. Blagdon (the Maintenance Superintendent) and many personnel of the Department of Civil Aviation, to whom cordial thanks is extended.

Gratitude is also expressed to various authorities of the Entomology Division, D.S.I.R., Nelson, (for identification of insect material); to Dr R.R. Forster (for identification of arachnids); to Mr P.M. Johns (for identification of miscellaneous insects); to Mr M.J. Hill (for identification of seeds); to Dr C. Burrows and Miss J. Ward (for identification of plants); to Mr J.M. Kelsey (for his advice on the insecticide trial); to Mr J.L. Burnip and Mrs J. Buckley (for preparation of photographs) and to Miss M. Stewart (for typing the final copy of the thesis).

This project was supported by a research grant sponsored by the Christchurch City Council, the National Airways Corporation and Air New Zealand.

REFERENCES

Aldrich, J.W., C.S. Robbins and W.W. Dykstra. 1961. Bird hazard to aircraft. Wildlife Leaflet 429, Branch of Wildlife Research, U.S. Department of Interior, 10pp.

Ballantyne, D.H. 1963. In discussion In Le problème des oiseaux sur les aèrodromes: 70p. Inst. Nat. Recherche Agronom., Paris.

Barthel, W.F., R.T. Murphy, W.G. Mitchell and C. Corley. 1970. The fate of heptachlor in the soil following granular application to the surface. J. Agr. Food Chem. 8(6): 445-447.

Besser, J.F., W.C. Royall and J.W. Degrazio. 1967. Baiting starlings with DRC-1339 at a cattle feedlot. J. Wildl. Mgmt. 31: 48-51.

Bird, W.H. 1965. Bird strike hazards can be reduced. Engineering Research and Development Department, Air Canada, Montreal, 19pp.

Bosse, I. 1967. Wiederbelebung biologisch verarmter Weinbergsböden, dargestellt am Beispiel des Regenwurmbesatzes. In Progress in Soil Biology. North-Holland Publishing Company, Amsterdam: 299-309. Ed. O. Graff and J.E. Satchell.

Briggs, J.B. 1961. A comparison of pitfall trapping and soil sampling in assessing populations of two species of ground beetles (Col.: Carabidae). Rep. E. Malling Res. Sta. (1960): 108-112.

Brough, T. 1968. Recent development in bird scaring. In The Problems of Birds as Pests. Academic Press: 29-38. Ed. R.K. Murton and E.N. Wright.

Brown, R.G.B. 1962. The reactions of gulls (Laridae) to distress calls. Ann. Epiphyties 13: 153-155.

Brown, E.M. 1963. In discussion In Le probleme des oiseaux sur les aèrodromes: 70p. Inst. Nat. Recherche Agronom., Paris.

Bull, R.M. 1964. Wellington Airport bird hazard survey. N.Z. Wildlife Service, Report.

---------- 1965. Interim bird hazard report, Tauranga Airport. N.Z. Wildlife Service, Report No. RMB:ER, 46/30/33.

---------- 1966a. Ohakea Airport, bird hazard survey: interim report. N.Z. Wildlife Service, Report No. 46/30/33.

---------- 1966b. Interim bird hazard report, Wellington Airport. N.Z. Wildlife Service, Report No. 46/80/33.

Busnel, R.G. and J. Giban. 1968. Prospective considerations concerning bio-acoustics in relation to bird-scaring techniques. In The Problems of Birds as Pests. Academic Press: 17-28. Ed. R.K. Murton and E.N. Wright.

Caithness, T.A. 1965. Interim bird hazard report, Whangarei Airfield. N.Z. Wildlife Service, Report.

--------------- 1966. A preliminary report on the bird hazard on Gisborne Airfield, with some recommendations for its abatement. N.Z. Wildlife Service, Report.

--------------- 1968a. Insects and birds on two New Zealand airfields. N.Z. Entomologist 4(1): 19-23.

--------------- 1968b. Poisoning gulls with alpha-chloralose near a New Zealand airfield. J. Wildl. Mgmt. 32(2): 270-286.

--------------- 1969. Bird hazards to aircraft research in New Zealand. Presented at the World Conference on Bird Hazards to Aircraft, Ontario, Canada, September 2-5.

Caithness, T.A. and M.J. Williams. 1965. Interim bird hazard report, Hawke's Bay Airfield - Napier. N.Z. Wildlife Service, Report No. MJW:ER 46/30/33.

Caithness, T.A., M.J. Williams and R.M. Bull. 1967. Birds and aircraft: a problem on some New Zealand airfields. Proc. N.Z. Ecol. Soc. 14: 58-62.

Clark, J.W. 1950. Effects of intense microwave radiation on living organisms. Proceedings of the I.R.E. 38: 1028-1032.

Cochran, W.G. and G.M. Cox. 1957. Experimental Designs. John Wiley and Sons, New York, 611pp.

Coleman, J.D. 1968. Aspects of the ecology of the rook _Corvus frugilegus frugilegus_ Linnaeus in Canterbury. M.Sc. Thesis, University of Canterbury (unpublished).

Cooke-Smith, R.A.W. 1963. Methods of clearing birds from United Kingdom civil aerodromes. _In_ Le problème des oiseaux sur les aerodromes: 131-135. Inst. Nat. Recherche Agronom., Paris.

Cottier, W. 1956. Insect pests. _In_ Plant Protection in New Zealand, Technical Correspondence School, N.Z. Department of Education, Government Printer, Wellington: 209-481.

De Cino, T.J., D.J. Cunningham and E.W. Schafer. 1966. Toxicity of DRC-1339 to starlings. J. Wildl. Mgmt. 30(2): 249-253.

Deichmann, W.B., F.H. Stephens, M. Keplinger and K.F. Lampe. 1959. Acute effects of microwave radiation on experimental animals (24,000 Megacycles). J. occup. Med. 1: 369-381.

Deichmann, W.B., J. Miale and K. Landeen. 1964. Effect of microwave radiation on the hemopoietic system of the rat. Toxic. appl. Pharmac. 6: 71-77.

Evans, A.C. and W.J.McL. Guild. 1947. Studies on the relationships between earthworms and soil fertility. I. Biological studies in the field. Ann. appl. Biol. 34(3): 307-330.

Ferguson, J. 1957. Beneficial soil microorganisms. California Agricultural Experimental Station, Manual 23, 237-254. Ed. K.F. Baker.

Fisher, R.A. and F. Yates. 1957. Statistical tables for biological, agricultural and medical research. Oliver and Boyd, London, 138pp.

Forster, R.R. 1954. The New Zealand Harvestmen (sub-order Laniatores). Canterbury Museum Bulletin No. 2, Christchurch, 329pp.

------------- 1967. The Spiders of New Zealand, Part I. Otago Museum Bulletin No. 1, Dunedin, 124pp.

Fowler, H.S. 1967. Bird distribution and strike data. Associate Committee on Bird Hazards to Aircraft, National Research Council, Canada. Field Note 42.

Fowler, H.S. and G.G. Levy. 1965a. A discussion of methods of testing bird-impact on windshields and other aircraft parts. Ibid. Field Note 26.

---------------------------- 1965b. A specific proposal for bird-impact testing on aircraft parts. Ibid. Field Note 28.

Frings, H., M. Frings, B. Cox and L. Peissner. 1955. Auditory and visual mechanisms in food-finding behavior of the Herring Gull. Wilson Bull. 67: 55-170.

Gerard, B.M. 1967. Factors affecting earthworms in pasture. J. Anim. Ecol. 36(1): 235-252.

Gibb, J. and P.H.T. Hartley. 1957. Bird foods and feeding-habits as subject for amateur research. Br. Birds 50: 278-291.

Goodwin, D. 1967. Pigeons and Doves of the World. The British Museum (Natural History) Publication No. 663, London, 446pp.

Greenslade, P.J.M. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). J. Anim. Ecol. 33: 301-310.

Grüm, L. 1959. Sezonowe zmiany aktywnosci biegaczowatych (Carabidae). Ekol. Pol. Ser. A 7(9): 255-268.

Gunn, W.W.H. and V.E.F. Solman. 1968. A bird warning system for aircraft in flight. In The Problem of Birds as Pests. Academic Press: 87-96. Ed. R.K. Murton and E.N. Wright.

Hardenberg, J.D.F. 1963. Clearance of birds on airports. In Le problème des oiseaux sur les aèrodromes: 121-126. Inst. Nat. Recherche Agronom., Paris.

Harris, R.D. and W.W.H. Gunn. 1964. In Associate Committee on Bird Hazards to Aircraft, National Research Council, Canada. Field Note 21.

Harris, R.D. and D. Hatch. 1964. Ibid. Field Note 20.

Hartley, P.H.T. 1948. The assessment of the food of birds. Ibis 90(3): 361-381.

Hess, G. 1951. The Bird: Its Life and Structure. Herbert Jenkins, London, 244pp. (English translation).

Hillaby, J. 1967. Birds versus aircraft. New Scient. 36(565): 18-20.

Hinde, R.A. 1961. Behaviour. In Biology and Comparative Physiology of Birds, Vol. II, 273-411. Ed. A.J. Marshall.

Hollom, P.A.D. 1950. Trapping methods for bird ringers. British trust for ornithology, field guide number one, Oxford, 40pp.

Kain, W.M. and R.W. Christie. 1966. Grass-grub control in problem soils. Proceedings of the Nineteenth New Zealand Weed and Pest Control Conference: 284-290.

Kuhring, M.S. 1963a. In discussion Le problème des oiseaux sur les aèrodromes: 69 Inst. Nat. Recherche Agronom., Paris.

------------- 1963b. An outline of the bird problem in Canada and what is being done about it. Ibid. 95-99.

------------- 1963c. Equipment used in Canada for dispersing birds. Ibid. 301-304.

------------- 1963d. Detection of birds on airfields at night with infrared equipment. Associate Committee on Bird Hazards to Aircraft, National Research Council, Canada. Field Note 4.

Lack, D.L. 1954. The natural regulation of animal numbers. Oxford: University Press, 343pp.

Lewis, H.F. 1964. Halifax International Airport - Bird hazard survey report. Associate Committee on Bird Hazards to Aircraft, National Research Council, Canada. Field Note 15.

Lewis, T. and L.R. Taylor. 1967. Introduction to Experimental Ecology. Academic Press, 401pp.

Martin, J.P. 1950. Use of acid, rose bengal, and streptomycin in the plate method for estimating soil fungi. Soil Sci. 69: 215-232.

Mitchell, B. 1963. Ecology of two carabid beetles, Bembidion lampros (Herbst.) and Trechus quadristriatus (Sehrank). J. Anim. Ecol. 32: 377-392.

Munro, D.A. and R.D. Harris. 1963. Du danger que constituent les oiseaux près des aèrodromes du Canada. In Le problème des oiseaux sur les aèrodromes: 173-206. Inst. Nat. Recherche Agronom., Paris.

Odum, E.P. 1962. Fundamentals of Ecology. W.B. Saunders Company, 546pp.

Peters, B.G. 1955. A note on simple methods of recovering Nematodes from soil. In Soil Zoology, 373-374. Butterworths, London. Ed. D.K.McE. Kevan.

Pramer, D. 1965. Life in the soil. Biological Sciences Curriculum Study, Committee on innovation in Laboratory Instruction, D.C. Heath and Company, Boston, 62pp.

Reinecke, A.J. and P.O. Ljungström. 1969. An ecological study of the earthworms from the banks of the Mooi River in Potchefstroom, South Africa. Pedobiologia 9: 106-111.

Rice, D.W. 1959. Birds and aircraft on Midway Islands, 1957-58 investigations. Branch of Wildlife Research, U.S. Department of Interior, Special Scientific Report - Wildlife No. 44.

Royall, W.C., T.J. De Cino and J.F. Besser. 1967. Reduction of a starling population at a turkey farm. Poultry Science 46(6): 1494-1495.

Rudd, R.L. 1964. Pesticides and the living landscape. The University of Wisconsin Press, Madison, 320pp.

Samolewicz, J.J. 1964. Temperature preference tests of sea-gulls. National Research Council, Canada, Test Report Met - 460.

Satchell, J.E. 1967. Lumbricidae. In Soil Biology, Academic Press: 259-321. Ed. A. Burges and F. Raw.

-------------- 1969. Methods of sampling earthworm populations. Pedobiologia 9: 20-25.

Saul, E.K. 1967. Birds and aircraft: a problem at Auckland's new international airport. J. Roy. Aeronaut. Soc. 71: 366-376.

---------- 1968. Birds at Whangarei Airport. N.Z. Wildlife Service, Report.

Solman, V.E.F. 1965. Use of falcons for airport bird control. Associate Committee on Bird Hazards to Aircraft, National Research Council, Canada. Field Note 33.

Southern, H.N. 1945. The economic importance of the house sparrow, Passer domesticus L.: a review. Ann. appl. Biol. 32: 57-67.

Southwood, T.R.E. 1966. Ecological methods, with particular reference to the study of insect populations. Methuen and Company Limited, London, 391pp.

Stable, E.R. and N.D. New. 1968. Birds and aircraft: the problems. In The Problems of Birds as Pests. Academic Press: 3-16p. Ed. R.K. Murton and E.N. Wright.

Stonehouse, B. 1964. Bird hazards at Christchurch International Airport, Harewood. Report addressed to the Chairman, Airport Committee of Christchurch City Council. October, 25, 1964.

-------------- 1966. Bird hazards at Christchurch International Airport, Harewood. Second Report, addressed to the Chairman, Airport Committee of Christchurch City Council, October, 12, 1966.

Svendsen, T.A. 1955. Earthworm population studies; a comparison of sampling methods. Nature, Lond. 175: 864p.

Tanner, J.A. 1966. Effect of microwave radiation on birds. Nature, Lond. 210: 636p.

Tanner, J.A., C. Romero-Sierra and S.J. Davie. 1967. Non-thermal effects of microwave radiation on birds. Ibid. 216: 1139p.

Tanner, J.A. and C. Romero-Sierra. 1968a. Microwaves vs birds - a new approach to the bird problem in aviation. Presented at 2nd Canadian Medical and Biological Engineering Conference, Toronto. September 9-11, 3pp.

---------------------------------- 1968b. Microwaves vs birds - effects on feeding behaviour. Presented at 21st ACEMB - Shamrock Hilton Hotel, Houston, Texas. November 18-21, 1968.

Tanner, J.A., C. Romero-Sierra and S.J. Davie. 1969. The effects of microwaves on birds - preliminary experiments. Presented in Journal of Microwave Power 4(2).

Van Tets, G.F. 1966. Birds and aircraft. Wildlife in Australia 3(4): 116-118.

Waksman, S.A. and R.L. Starkey. 1931. The soil and the microbe. John Wiley and Sons, New York, 260pp.

Wallace, G.J. 1955. An Introduction to Ornithology. The Macmillan Company, New York, 443pp.

Ward, P. 1965. Feeding ecology of the Black-faced Dioch _Quelea quelea_ in Nigeria. Ibis 107: 173-214.

Welty, J.C. 1962. The Life of Birds. W.B. Saunders Company, Philadelphia and London, 546pp.

West, R.R. 1968. Reduction of a winter starling population by baiting its preroosting areas. J. Wildl. Mgmt. 32(3): 637-640.

Williams, M.J. 1966a. Report on bird hazard to aircraft at Momona Airport - Dunedin. N.Z. Wildlife Service, Report.

Williams, M.J. 1966b. Interim report on the bird hazard at Invercargill Airport. N.Z. Wildlife Service, Report.

Williams, M.J. and T.A. Caithness. 1965. Interim bird hazard report - Wellington Airport. N.Z. Wildlife Service, Report.

Wright, E.N. 1968. Modification of the habitat as a means of bird control. In The Problem of Birds as Pests. Academic Press: 97-105. Ed. R.K. Murton and E.N. Wright.

Zicsi, A. 1967. Die Auswirkung von Bodenbearbeilungsverfahren auf Zustand und Besatzdichte von einheimischen Regenwürmern. In Progress in Soil Biology. North-Holland Publishing Company, Amsterdam: 290-298. Ed. O. Graff and J.E. Satchell.

APPENDIX I. Percentage (quantitative) food composition of Black-billed Gulls, Magpies and Starlings.

L = Larvae

Months	Species	Col.	Orth.	Dip.	Lep.	Hem.	Der.	Arach.	Lumb.
March 1968	Black-billed Gull	10.4	7.3	26.4	51.8	0.0	0.0	1.5	2.4
	Magpie	87.9	2.8	2.8	1.0	1.0	0.7	1.8	1.4
		L. 0.3							
	Starling	52.2	7.3	2.2	8.8	2.9	2.2	2.9	5.1
		L. 6.6							
April 1968	Black-billed Gull	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.3
		L. 43.7							
	Magpie	59.1	23.6	5.6	0.0	0.6	0.6	4.3	3.1
		L. 0.6			2.5				
	Starling	35.5	21.5	1.5	2.2	9.6	0.4	2.2	5.2
		12.6			8.9				
May 1968	Black-billed Gull	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.3
		L. 43.7							
	Magpie	49.6	10.4	1.6	0.0	0.0	1.6	8.8	1.6
		L. 13.6			12.8				
	Starling	19.6	7.4	0.3	0.0	5.0	0.9	1.8	2.4
		L. 46.7			15.8				
June 1968	Black-billed Gull	12.4	4.3	4.3	0.0	0.0	0.0	0.0	16.9
		L. 63.7							
	Magpie	23.4	22.1	2.2	0.0	3.7	2.5	0.0	3.1
		L. 7.4			35.5				
	Starling	31.9	0.7	0.0	0.0	0.0	1.0	0.4	9.5
		L. 38.8			17.5				
July 1968	Black-billed Gull	26.1	0.0	4.3	0.0	0.0	0.0	0.0	34.8
		L. 34.8							
	Magpie	70.3	0.0	0.0	0.0	0.0	3.5	3.4	5.3
	Starling	24.5	0.7	0.4	0.0	5.6	0.7	2.0	2.6
		L. 45.2			18.2				
August 1968	Black-billed Gull	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.1
		L. 65.6			21.2				
	Magpie	55.5	0.0	0.0	0.0	6.2	1.2	7.4	0.0
		L. 4.9			24.7				
	Starling	27.8	0.0	0.0	0.0	1.0	1.0	4.4	4.9
		L. 27.8			33.2				

APPENDIX I (cont'd).

Months	Species		Col.	Orth.	Dip.	Lep.	Hem.	Der.	Arach.	Lumb.
September 1968	Black-billed Gull		9.1	0.0	0.0	0.0	0.0	0.6	1.6	15.7
		L.	22.5			50.3				
	Magpie		27.3	0.0	0.9	0.0	0.5	9.6	4.8	2.4
		L.	18.7			35.9				
	Starling		17.6	0.0	0.8	0.0	0.0	4.6	2.7	1.1
		L.	24.4			48.8				
October 1968	Black-billed Gull		- - - - - - no sample - - - - - -							
	Magpie		47.2	0.0	0.0	0.0	0.0	6.6	4.4	0.0
		L.				41.8				
	Starling		29.9	0.0	1.3	0.3	0.8	0.6	11.9	0.0
		L.	1.4			53.9				
November 1968	Black-billed Gull		- - - - - - no sample - - - - - -							
	Magpie		86.4	0.3	3.8	0.3	1.8	0.6	2.7	0.0
		L.				4.1				
	Starling		67.1	0.5	18.3	0.9	2.4	0.2	8.9	0.0
		L.				1.6				
December 1968	Black-billed Gull		- - - - - - no sample - - - - - -							
	Magpie		68.5	6.4	3.7	8.2	10.5	0.0	1.1	0.0
		L.	1.5							
	Starling		47.5	0.4	0.6	2.7	26.8	0.1	2.5	0.0
		L.	0.3			19.0				
January 1969	Black-billed Gull		- - - - - - no sample - - - - - -							
	Magpie		10.5	0.0	0.5	18.5	14.6	0.1	0.1	0.0
		L.				55.4				
	Starling		38.9	3.7	0.4	7.3	15.2	9.1	3.8	0.0
		L.			18.6	3.0				
February 1969	Black-billed Gull		- - - - - - no sample - - - - - -							
	Magpie		44.4	10.1	4.4	6.9	18.8	0.8	3.6	0.0
		L.				10.9				
	Starling		62.1	8.4	2.5	8.8	10.7	2.1	3.0	0.0
		L.	2.3							
March 1969	Black-billed Gull		0.0	6.9	0.8	5.3	0.0	4.8	2.8	18.6
		L.	68.7							
	Magpie		67.5	0.9	2.2	14.0	0.7	2.4	3.6	0.0
		L.			0.3	8.1				
	Starling		43.1	12.3	6.4	5.6	13.5	1.9	3.0	1.1
		L.	11.2			1.9				

APPENDIX II. Food of nine Skylarks (*Alaudea arvensis*) from Christchurch Airport pasture. For sample dates see Table 13.

		Frequency	No. of individuals
Invertebrate			
Insects			
Adult			
Melampsalta sp.		1	2
Nysius sp.		2	3
Costelytra zealandica		4	7
Phaulacridium marginale		1	1
Crambus sp.		2	2
Carabidae	(Unid.)	5	72
Curculionidae	(")	6	41
Elateridae	(")	1	1
Lepidoptera	(")	2	3
Diptera	(")	2	3
Larvae			
Coleophora sp.		3	9
Lepidoptera	(Unid.)	2	2
Arachnid			
Araneida	(Unid.)	1	2
Plant material			
Seed			
Stellaria media		5	461
Chenopodium album		2	10
Anthoxanthum odoratum		2	34
Erodium sp.		8	44
Poa sp.		2	135
Stipa sp.		2	28
Polygonum sp.		2	12
Trifolium sp.		2	3
Oxalis sp.		1	36

APPENDIX III. Food of five N.Z. Pipits (*Anthus novaeseelandiae*) from Christchurch Airport pasture. For sample dates see Table 13.

	Frequency	No. of individuals
Invertebrate		
Insects		
Adult		
Coccinella undecimpunctata	1	1
Costelytra zealandica	2	2
Nysius sp.	4	10
Curculionidae (Unid.)	4	44
Carabidae (")	2	10
Diptera (")	2	30
Larvae		
Coleophora sp.	1	3
Crambus sp. and *Aletia* sp.	1	2
Arachnids		
Araneida (Unid.)	1	3
Opiliones (")	1	2
Plant material		
Seed		
Stellaria media	1	130
Poa sp.	2	50
Erodium sp.	2	57
Trifolium sp.	1	80
Oxalis sp.	1	7
Polygonum sp.	1	2

APPENDIX IV. Protozoa culture media (After Pramer, 1965).

The media consisted of the following constituents with the quantities mentioned.

Soil extract	500 ml
Water	500 "
Glucose	1 g
Yeast extract	0.5 "
K_2HPO_4 (di-Potassium Hydrogen Orthophosphate)	0.5 "
Agar	15 "

The soil extract was prepared by mixing 500 g of garden soil into 1500 ml of water. The suspension was autoclaved at 15 p.s.i. for 30 minutes and was then allowed to settle before filtering to obtain a clear extract. The volume was later adjusted to 1000 ml. The soil extract was then added to the other constituents of the media. The total mixture was autoclaved at 15 p.s.i. for 20 minutes before use.

APPENDIX V. Bacteria culture media.

Standard "Difco Bacto Nutrient Agar" media was used. Ingredients per litre:

Bacto - Beef extract	3 g
Bacto - Peptone	5 "
Bacto - Agar	15 "

APPENDIX VI. Fungi culture media (F.H. Wood, pers. comm.)

Potato-Dextrose Agar (PDA) media was prepared as follows:

Constituents	
Agar	12 g
Potato (peeled and sliced)	200 "
Dextrose	10 "
Water (distilled)	1000 ml
Added	
Rose Bengal	60 mg/litre
Streptomycin Sulphate	30 "/ "

Potato chips were cooked for an hour in 500 ml of water, the mixture filtered through cheesecloth and the filtrate retained. Agar and dextrose were added to another 500 ml of water and the solutions combined. The total volume was adjusted to 1000 ml before autoclaving at 15 p.s.i. for 20 minutes. Rose Bengal and Streptomycin were then added to the total volume to inhibit bacterial growth and also to restrict fungal growth slightly to facilitate counting discrete colonies. The whole media is also known as Martin's (1950) media.

APPENDIX VII. Algal culture media (after Pramer, 1965)

Six 400 ml solutions in distilled water were prepared in separate flasks. Each containing one of the following salts and the quantity mentioned.

Na NO_3	(Sodium Nitrate)	10 g
Na Cl	(Sodium Chloride)	1 "
Mg SO_4	(Magnesium Sulphate)	3 "
Ca Cl_2	(Calcium Chloride)	1 "
KH_2PO_4	(Potassium Hydrogen Orthophosphate)	7 "
K_2HPO_4	(di-Potassium Hydrogen Orthophosphate)	3 "

After thorough mixing, 10 ml from each solution was added to 940 ml of distilled water. One drop of 1% Fe Cl_3 (Ferric Chloride) solution was then added to the one litre of total media.